This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

MANUAL
OF
COMPARATIVE ANATOMY
AND
PHYSIOLOGY

S. MESSENGER BRADLEY

MANUAL

OF

COMPARATIVE ANATOMY

AND

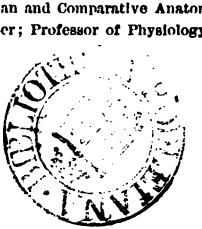
PHYSIOLOGY.

BY

S. MESSENGER BRADLEY,

F.R.C.S. EXAM.

Lecturer on Human and Comparative Anatomy, Royal School of Medicine, Manchester; Professor of Physiology, Stonyhurst College.



LONDON:

SIMPKIN, MARSHALL, AND CO.

MANCHESTER: J. E. CORNISH.

1870.

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET

PREFACE.

THE works on Comparative Anatomy and Physiology are so numerous, and many of them so splendid, that some apology seems necessary for the issue of such a sketch as the present little Manual. It is found in the very perfection of former treatises on the subject; a perfection which renders them so bulky and comprehensive, as almost to preclude students, who have a multiplicity of other subjects to prepare, from gaining the particular facts they require, for they naturally dread *tentare horridas vias* of such large tomes as those of Rymer Jones or Owen. This difficulty is particularly felt by gentlemen who are preparing for their second B.A. at the London University. It is a perfectly well-known fact to those who come much in contact with men going up for this examination, that their 'bête noir' is the *Animal Physiology* which forms one of the subjects, and it is with the definite hope of, in some slight measure, smoothing away this difficulty, that the following little Treatise has been *prepared.* The principal merit which it possesses,

that of brevity, would have been rendered impossible if the ordinary processes of physiology, which form the subject matter of works on human physiology, had been described; nor is the omission of such matter to be lamented, as manuals of the greatest excellence upon this subject are within the reach of every student.

CONTENTS.

CHAP.		PAGE
I.	Animal and Vegetable Cells. Differences between Plants and Animals. Divisions of Animal Kingdom	1
II.	Protozoa	4
III.	Cœlenterata	8
IV.	Annuloida	12
V.	Annulosa	17
VI.	Molluscoida	27
VII.	Mollusca	31
VIII.	Vertebrata	39
IX.	Generative Organs and Mode of Reproduction amongst the Oviparous Vertebrata	81
X.	Generative Organs and Mode of Reproduction amongst Mammalia	85
XI.	Development of Vertebrates	
XII.	Professor Huxley's Classification of Vertebrates	
XIII.	Answers to Examination Papers	97

MANUAL OF COMPARATIVE ANATOMY AND PHYSIOLOGY.

CHAPTER I.

ALL animals, from the shapeless protozoon to man, are developed from cells; and all the various tissues of every animal are originally composed of similar cells, and a similar intercellular matrix, or *blastema* (βλαστός, a germ).

A perfect animal cell consists of a very thin cell wall or envelope, the *periplast*; of semi-fluid contents, the *endoplast*; of an exceedingly minute vesicular body, the *nucleus*, within which are generally found still minuter bodies, the *nucleoli*. The *endoplast* is made up of fat particles, granules, and a transparent substance, partly albuminous and partly amyloid, the *protoplasm*.

New cells are formed in various ways. By one mode, a cell and its contained nucleus splits into two distinct cells, each containing its proper nucleus. This is the *fissiparous* mode of development. By another method, a cell develops a small bud from one part of its envelope, which, after growing, becomes detached from the parent cell, and assumes the form and function of a perfect cell. This is *gemmiparous* development. A third plan is for the nucleus to divide into one, two, or more nuclei, which either burst their way out of the cell wall,

and then become developed into perfect cells, *exogenous* development; or, after their division, grow up within the envelope of the parent cell into mature cells, *endogenous* development. Their multiplication thus provided for, animal cells undergo various changes in form and composition. Some lengthen out into thin thread-like bodies, which, becoming connected end to end of other similar cells, constitute the histological elements of the fibrous tissues; others remain as circular cells with or without *periplast*, and constitute the cells of the blood, the chyle, &c.; others become loaded with earthy or calcareous particles, and so build up the skeletons of animals; others become converted into skin, by being flattened out and dried; others, again, remain distinctly cellular, and constitute the animal secretions.

There is very little difference between the individual *vegetable* and *animal* cell; but the points to be chiefly noted are these. The *vegetable* cells are always *perfect* cells; they are surrounded by very little blastema, they are mutually independent of each other, and they require for their nourishment a pabulum drawn from the inorganic world. On the other hand, *animal* cells are frequently *imperfect*, being deficient in a cell wall; they are always surrounded by a considerable amount of blastema, they are mutually dependent on each other, and they derive their nourishment from the organic world alone. By this latter property the two kingdoms supplement each other's requirements, and so maintain the natural cycle of life. The animal dies, and is resolved into the inorganic world, in which condition he becomes food for the plant; the *plant then re-converts this pabulum into organic matter, when it re-becomes meet food for the animal.*

The dawn of animal life is, as may be gathered from what has gone before, indistinct, and often difficult to discern. The border-land between the vegetable and animal kingdom is the scene of a perpetual conflict of opinion, doubtful forms changing sides more than once during the contest. Perhaps the most important differential characteristics of animals are, first, the fact of their food being always derived from the organic world, and, secondly, the fact that in their physiological processes they are *synthetical*, whilst vegetables are *analytical*; in other words, animals take in oxygen and give out carbonic acid, which is formed in their system; whilst plants take in carbonic acid, and, breaking it up into its component parts, give out the oxygen and retain the carbon.

The whole animal kindgom is divided into sub-kingdoms, classes, families, genera, orders, species and varieties, with constantly less important and diminishing lines of demarcation between the divisions as we descend the list. The sub-kingdoms at present recognised are

Vertebrata.

Mollusca.	Annulosa.
Molluscoida.	Annuloida.

Cœlenterata.

Protozoa.

Protozoa is clearly the lowest sub-kingdom, Vertebrata as certainly the highest. It is to be observed, however, that we do not reach Vertebrata by a single line, but that the sub-kingdom Cœlenterata branches into two streams, each of which conducts us to the top of the animal ladder.

CHAPTER II.

SUB-KINGDOM I.—PROTOZOA.

PROTOZOA.—πρῶτος, *first*; ζῷον, *living creature.* Synonym, *Acrita.*

Definition.—Minute animals composed of a soft mass, called sarcode, covered with cilia. The sarcode contains vesicles which constantly change their shape, owing to a power of contraction residing in the protoplasm, and similar to muscular action. They possess neither nervous system, circulatory organs, or alimentary canal. They are as a rule fissiparous or gemmiparous in their reproduction: a few multiply by sexual intercourse.

Protozoa are divided into those without any oral orifice, *Astomata*, and those possessed of a mouth, *Stomata.*

They contain the following classes and orders:—

ASTOMATA.	STOMATA.
Classes.	Classes.
1. Gregarinida.	1. Infusoria.
Orders.	Orders.
Protogenes.	Paramecium.
Amœbæ.	Acineta.
2. Rhizopoda.	Noctiluca.
Foraminifera.	
3. Spongida.	
4. Radiolaria.	
Polycystinæ.	
Thalassicollæ.	

Gregarinida (gregarius, grex, *a flock*) comprise *the simplest of all* animal forms. They are micro-

scopic and parasitic, and have an elongated envelope, which undergoes changes in form, first elongating and then contracting.

The simplest of these amorphous forms, the *Protogenes*, is unicellular indeed, and affords an example of a living creature consisting of nothing but a single animal cell; this cell, however, is capable of absorbing nutriment, and converting it into its own substance.

Amœbæ are named from the Protean changes of shape which they undergo; these changes being produced by first one part of the sarcode contracting, and then another.

Rhizopoda (*ῥίζα, a root*; *πούς, a foot*). — The sarcode of these minute organisms is prolonged into thread-like processes, which project from various parts of the animal's body. The soft mass is most frequently enclosed in delicate lime shells, perforated by numerous foramina, through which the long processes, or pseudopodia, project.

Foraminifera.—Microscopic though the foraminifera are, yet so vast are their numbers, that they constitute large tracts of land in many parts of the world. Their shells are many-chambered, and the majority of them very lovely, affording objects of interest to the microscopist.

Spongida constitute a large and important class of Protozoa. What we familiarly call a sponge, is in fact the skeleton of a colony of Spongida. The so-called sponge is covered over with the gelatinous sarcode which has, in the first place, secreted the silicious support. The sponge is pierced by numberless apertures, some small and very numerous, others large and fewer in number. The small apertures suck in the sea water, which is then passed through every part of the sponge, and de-

prived of any floating organic matter it may contain, and finally ejected through the large apertures.

In this way is a respiratory, circulatory, and digestive apparatus first sketched in the animal world.

Spongida are also interesting from being often reproduced by sexual intercourse, and because spermatozoa are met with for the first time. Many sponges, however, multiply gemmiparously. The young sponge bud, covered with cilia, at first swims about freely, but at last glues itself to some foreign body, and increasing in size, remains stationary for the rest of its life.

Radiolaria are minute oceanic animals. Their sarcode is jelly-like.

Polycystinæ have a silicious skeleton, and some yellow granules which are supposed to act as excretory organs.

Thalassicollæ have no skeleton, but are made up of a glue-like mass, as their name implies.

The *Stomata* only contain one large class, the **Infusoria.**

The Infusoria are manifestly the most highly organised of all the Protozoa, and are sometimes elevated to the position of a distinct sub-kingdom. The body is unsymmetrical, but the sarcode is always surrounded by a firm envelope. The sarcode always contains a nucleus and nucleolus. The oral aperture is surrounded by cilia, which are always moving automatically, and act as respiratory and digestive organs. The contractile vesicles are numerous, and regularly arranged.

Paramecium are fresh-water Infusoria, shaped like a tiny slipper, with characters as above.

Vorticella embrace the stalked forms of Infusoria; each stalk contains contractile sarcode.

Acineta possess neither mouth nor outlet of any kind; but there are numerous hollow processes which radiate from the body, and serve as organs of prehension. Critically, the *Acineta* should be classed with the *Astomata*.

Noctiluca.—These are the minute organisms that in infinite numbers constitute the 'phosphorescent sea.' To the naked eye, and even to the microscope, there is no beauty in them; all that is seen is a simple sac with numerous vacuoles, some granular matter, an oral aperture, and a tail; but at night, these plain beings light up the ocean as with myriads of tiny lamps, and turn the whole waves to sheets of liquid fire.

Physiological Processes of Protozoa.

The physiological processes of the Protozoa are confined to the phenomena of digestion. The food, which often consists of a still tinier organism than the diner, is absorbed into the general sarcodous mass; the digestible parts are absorbed, while the indigestible are rejected through any part of the envelope that happens to be in closest propinquity to the morsel.

CHAPTER III.

SUB-KINGDOM II.—CŒLENTERATA.

CŒLENTERATA (κοῖλος, *hollow*; ἔντερον, *intestine*). Synonym, *Nematoneura*.

Definition.—Aquatic animals. Frequently resemble flowers in their general appearance. Substance of body soft and semi-transparent, surrounded by a denser envelope without and within, called respectively the 'ectoderm' and the 'endoderm.' The ectoderm often contains little spaces, in which are situated thread-like organs, endowed with urticating properties. One opening leads into the interior of the body, which serves for both mouth and anus.

The nervous system, when discoverable, consists of a single ganglion, whence filaments radiate to distant parts of the body. The ganglion is placed opposite the oral aperture.

No organs of circulation exist. The mouth is surrounded by tentacles, which are never ciliated.

The Cœlenterata split into two classes.

1. **Actinozoa.**—They have a distinct digestive cavity, and their organs of reproduction are internal.

2. **Hydrozoa.**—They have no distinct digestive cavity, and their organs of reproduction are external.

Class.	Class.
ACTINOZOA.	HYDROZOA.
Orders.	Orders.
1. Actiniæ.	1. Acalephæ.
2. Alcyonidæ.	2. Hydræ.
3. Madreporidæ.	3. Tubularidæ.
4. Corallidæ.	4. Sertularidæ.
5. Pennatulidæ.	5. Campanularidæ.

Actiniæ form a beautiful order of Actinozoa, which, from their peculiar form, are often termed animal flowers. They form important ornaments in every salt-water aquarium, and are well known as sea anemones.

Alcyonidæ are compound polyps—soft in structure. The little polyps which go to make up the colony being situated upon the soft gelatinous envelope, like sessile buds upon a stalk. In all these compound polyps there is a community in their physiological processes; thus whatever a single polyp catches and eats goes to afford nourishment to the entire mass.

Madreporidæ, *Corallidæ*, *Pennatulidæ*—a common description will serve for these three orders of Cœlenterata.

Corallidæ, Madreporidæ, Pennatulidæ, form three large orders of Actinozoa. In all, the calcareous basis of support is secreted by the living gelatinous masses of minute Actinozoa which cover it. The coral reefs and islands consist of this calcareous support or skeleton coated with the living colony.

Acalephæ or *Medusæ*.—This order comprises the jelly fishes, or sea nettles. Their bodies are soft, but sometimes, as in the genus Cirrigrada, there is a trace of an internal cartilaginous skeleton. They all possess urticating organs, called *thread cells*, which they can protrude and employ at pleasure. Their movements are effected by muscular contraction. The muscular fibres are very pale and indistinct, but are said to resemble the unstriped muscle of the human subject. The sense of sight makes its first appearance in the animal series in this group, in the shape of *eye spots*. A nerve passes from the principal ganglion to some part of the ectoderm, where it expands into a nervous membrane, behind which we find a pigmentary tunic. This is the mode of con-

struction of 'eye spots,' or 'ocelli,' wherever met with in the animal kingdom.

Organs of hearing are also met with, placed at the base of the tentacles.

The life history of an acaleph is as follows. The ovum, which is the production of two parents, in other words of bisexual organs, grows up with a segmented, elongated body; each disc-like segment, becoming separated from the rest, floats about as a perfectly free animal, and is called a *Planula*. This minute animal, $\frac{1}{8}$-inch in diameter, rapidly develops, its rays become short and disappear, while its oral tentacles and *nemato-cysts*, or *thread cells*, make their appearance, when the young acaleph is complete in all its parts.

Hydræ are minute fresh-water polyps, common in every stagnant pool at certain seasons of the year.

Tubularidæ, *Sertularidæ*, *Campanularidæ*, are three orders of Hydrozoa, common enough on our coasts. They are all more or less like each other, and all differ from the *Hydræ* in possessing a horny internal supporting stem or *polypary*, and again, in the fact that each newly-formed offset or 'gemma' remains attached to the parent stock, whereas in the Hydræ such buds always become detached from the parent, and developed into perfect Hydræ.

Physiological Processes of Cœlenterata.

The physiological processes of Cœlenterata are more extensive than those of Protozoa.

Digestion is effected by means of the absorbing powers of the endoderm. If the animal be turned inside out, the ectoderm, now become the endoderm, *will digest food* equally well. Indigestible matters *are returned* through the common inlet or oral

aperture. In the compound Hydrozoa the lower part of the body-cavity of each polyp communicates with a tube in the polypary which is common to the whole colony.

Circulation and *Respiration*.—No organs set-apart for either of these processes are met with in Cœlenterata.

The *Nervous System*, composed of a ganglion, with afferent and efferent nerves, acts generally in a reflex manner, and regulates the muscular movements of the class. It is also capable of a sensori-motor and sympathetic action. The movements are not volitional. Nerves pass both to the eye-spots and auditory sacs.

CHAPTER IV.

SUB-KINGDOM III.—ANNULÓIDA.

ANNULOIDA. — Synonyms, *Nematoneura* (Owen), *Radiata* (Cuvier).

Definition.—Symmetrical animals. In most cases possessed of a set of tubes which traverse the interior of the animal, and open by separate points on the exterior, forming the 'water-vascular system.' The nervous system is symmetrically arranged, one or more ganglia are placed upon or above the gullet, whence nerves radiate to the different parts of the body. The Annuloida generally exhibit, in their reproduction, what is termed 'alternate generation'; by which is signified the fact, that the ova grow up into forms which do not at all resemble their parents, but give birth to secondary ova which in their turn revert to the original type. This reversion does not always take place in the second, but occasionally occupies several, generations. Annuloida contain the two following classes:—*

Class. I. SCOLECIDA. Orders.	Class. II. ECHINODERMATA. Orders.
1. Trematoda—*Flukes.*	1. Asteridea—*Starfish.*
2. Turbellaria.	2. Echinidea—*Sea urchins.*
3. Rotifera—*Wheel animalcules.*	3. Holothuridea—*Sea cucumbers.*
4. Tæniada—*Tape-worms.*	4. Ophiuridea — *Trepangs.*
5. Nematoidea—*Thread-worms.*	5. Crinoidea—*Feather-stars.*
6. Acanthocephala—*Hydatids.*	
7. Gordiacea	

* Vide page 99.

Scolecidæ (*σκώληξ, a worm*).—All the Scolecidæ possess a water-vascular system: the greater part of them are parasitic, and develop by 'alternate generations.'

Trematoda are parasitic worms, chiefly infesting the livers of sheep and other animals. They are hermaphrodite and self-impregnating. The ova pass through an alternation of generations.

Turbellaria are marine and fresh-water worms, often attaining a great size, as *e.g. Nemertes Borlassii*, which grows to a length of thirty feet. The Turbellaria possess cilia, which act as prehensile organs.

Rotifera are microscopic animals, and receive their name from the fact of their possessing cilia around the mouth, called the *trochal disk*, which are perpetually vibrating.

Tæniada.—These parasitic, jointed worms consist of a round head, which is called the rostellum (it possesses a circlet of hooks and four small suckers), and many segments, which are termed proglottides. Each proglottis is hermaphrodite and self-impregnating. The Tæniada well illustrate the process of 'alternate generation.' Their life history is as follows: First.—The egg being extruded from the body of the animal, in which its parent was parasitic, grows up into a round vesicular-like worm, armed with hooklets and suckers, and provided with a tail; in this condition it reaches the second stage, and is called a *Cysticercus*. The Cysticercus has to be conveyed into the intestinal canal of some animal before the further changes take place. When the worm in this condition (the Scolex) has reached the duodenum of the animal it requires for its development, it loses its tail, and gradually forms segment after segment of its body; each segment becomes provided with generative pores which lodge both male and female organs; the

animal has now reached the third and final stage of a true *Tænia*. The most mature segments, which of course are nearest the tail, are termed proglottides; these after self-impregnation drop off, and, with their contained ova, are passed away. The most usual plan is for the Scolex or Cysticercus to be eaten by some animal, which in turn is eaten by another.

Nematoidea are a numerous order of Scolecidæ, and contain both free and parasitic worms. The formidable *Trichina*, and the troublesome little *Ascaris*, are members of this group. They are distinguished by two long tubes which traverse the entire length of the animal, and which are supposed to be representatives of the water-vascular system.

Acanthocephali are worm-like parasites, and include the Echinorynchus.

Gordiacea are filiform parasites, and inhabit the bodies of insects.

Echinodermata (echinus, *a hedgehog*; δέρμα, *the skin*).—The Echinodermata are much more perfectly definable than the Scolecidæ. They all possess a calcareous framework more or less perfect. In nearly all, the ovum develops into a ciliated free swimming larva, totally different to the adult animal; the larva at length develops a calcareous enveloping framework, within which the future animal is produced. The Echinodermata possess certain vessels and organs which have reference to locomotion, and are called consequently 'ambulacral vessels.' They are the homologues of the 'water-vascular system' of Scolecidæ.

Asteridea.—Radially symmetrical animals, with the ambulacral vessels radiating from the centre of the star to the end of the rays; through these tubes *project the sucker-feet*. Asteridea possess an oral *aperture on the* dorsal aspect, and an anal aperture *on the ventral* aspect of the body.

Echinidea closely resemble a hedgehog, as their ıme implies. There are five rows of ambucral furrows, through which the sucker-feet project; l of these furrows are arranged radially. The ıtestinal canal is well developed and reaches from ıe pole of the animal to the other: between the ıtestinal canal and the walls is placed a space ırmed the *perivisceral cavity*. The gullet is surɔunded by a nervous collar, whence nerves pass to ıe five different parts of the body, each nerve terıinating in an eye-spot situated near the anus. The ːal aperture is guarded by five very perfect teeth, ɹoved by distinct muscles and capable of a variety ː movements. These constitute the well-known Aristotle's lantern:' it is the first specimen of a ɛntary apparatus in the animal kingdom, but it ɔrings into being, like Minerva from the head of ɔve, perfect at all points.

Holothuridea.—This order may be likened to the ırmer, supposing an echinus to be stretched out ıto a sausage-like body, and the regularly disposed ılcareous plates of the echinus exchanged for ːattered masses.

Ophiuridea closely resemble ordinary star-fish, but ıeir arms or rays are much slenderer, and the cenal part much smaller. It is doubtful whether any ɔmmunication exists between the ambulacral system ıd the exterior.

Crinoidea much resemble the former, but it is even ore doubtful whether such communication between ıe ambulacral system and the exterior exists.

Physiological Processes of the Annuloida.

Digestion.—The organs of digestion are much *ore perfect* than we have met with previously. All ə *Scolecidæ*, except the Tæniada and the Acantho-

cephala, possess an alimentary canal, which, i
Trematoda, the Gordiacea, and Turbellaria ha
one inlet and no outlet; in the Rotifera, the N
toidea and some Turbellaria, there is both a
and an anal aperture, and very often a phary
dilatation or crop. All the Echinodermata h
well-developed intestinal canal, distinct fro
walls of the body, and provided with both or
anal apertures, which are situated directly op
each other.

Circulation and Respiration. — The only
present for the performance of these functio
the water-vascular systems of the Scolecidæ, a
ambulacral vessels of the Echinodermata.
subserve the double purpose of circulator
respiratory organs. Most of the ambulacral
are lined with cilia.

Nervous System.—Only possessed of a se
motor and excito-motor power. No real v
yet present. In other words, all the movemer
of a reflex character; there is a low degree c
sation in some.

CHAPTER V.

SUB-KINGDOM IV.—ANNULOSA.

ANNULOSA.—Synonyms, *Homogangliata* (Owen); *Articulata* (Cuvier).

Definition.—The body of the *Annulosa* is divided into segments, called somites, which are arranged in a longitudinal manner. The covering of these somites is dense, and gives insertion to powerful muscles. The nervous system is very well developed, and always arranged in a definite way, and a way which is peculiar to this sub-kingdom. The gullet is surrounded by a nervous collar, with one large ganglion (*supra-œsophageal*) above the gullet, and from this collar a double gangliated cord, two ganglia for each segment, succeeds, which passes down the whole *ventral* aspect of the animal.

Annulosa are primarily divided into two great groups, sometimes considered even to constitute separate sub-kingdoms, called respectively Arthropoda and Annelida: the distinctive characters of each of these we must define.

Arthropoda (*ἄρθρον, a joint*; *πούς, a foot*) always possess articulated limbs, appended to a dense exoskeleton. There is perfect bilateral symmetry in all the parts of the body, both external and internal. The organs of vision are highly developed. The jaws move transversely, and the head is supplied with feelers and antennæ. Neither the embryotic or adult arthropod ever possesses cilia. In place of a heart they possess a distinct dorsal vessel, which is *valved, and* contracts rhythmically.

Annelida (anellus, dim. of annulus, *a ring*).—The covering of the body is soft, and does not give support to jointed limbs. The organs of sense are very simple. There is no distinct valved contractile dorsal vessel; but nearly all possess peculiar vessels called *pseudo-hæmal*, which contain a corpusculated fluid. The embryo or adult possesses cilia. The Annelida are generally ranked as a class.

The *Arthropoda* contain the following classes:—

Classes.

1. Myriapoda.
2. Arachnida.
3. Crustacea.
4. Insecta.

Myriapoda include the centipedes and millipedes. They are characterised by the body being composed of more than twenty somites; to each of the segments legs are appended. The segments increase in number with increasing age. This fact distinguishes them from Insecta. The head consists of six somites, more or less welded together. The covering is very firm and hard. The air is drawn in through little holes or *spiracles*, situated upon the surface, and conveyed to tubes, called *tracheæ*, by means of which it is distributed to the entire body.

Arachnida.—The somites in the higher Arachnida number twenty. They are collected into two masses, one forming a cephalo-thorax and the other an abdomen. There are four pairs of legs. The breathing is peculiar, there being an involution of the integument to form a pulmonary sac which receives the air directly. The eyes are always sessile and generally *simple*. This class comprises the scorpions, spiders, mites, and ticks.

Crustacea.—This large class always possesses a dense *chitinous* integument. The somites are of variable number, and to some of them articulated appendages

are attached. The breathing is always aquatic, and carried on by means of gills, or branchiæ. The circulatory organ, when present, is always placed on the dorsal aspect, the nervous ganglia being on the ventral aspect. This class comprises the crabs, lobsters, and king-crabs.

Insecta.—The class of Insecta contains more species than all the rest of the animal kingdom put together, there being 150,000 already defined; but it is distinguished very readily from all the rest by perfectly definite characteristics.

The body is divided into three segments: a head, thorax, and abdomen.

The head contains the organs of sense, and supports two antennæ. The eyes are always compound.

The thorax consists of three somites, which always support three pairs of articulated legs, and sometimes gives attachment to two or four wings.

The abdomen, composed of eleven somites, more or less welded together, contains the viscera and organs of reproduction. Legs are never attached to the abdomen.

The respiration of insects is effected by means of tracheæ, which ramify through every part of the body. Many insects pass through certain metamorphoses, as follows:—

The female insect lays eggs, which grow up into *caterpillars*; in this stage the insect is called a *larva*. This larva, after laying up good store of food, goes to sleep and becomes wrapped up in a mummy-like case, when it constitutes the *chrysalis*, *nympha*, or *pupa*; this is the second stage of insect metamorphosis. The third and last is reached by the insect bursting its swathing-bands and becoming a gay denizen of the air; this, the perfect insect, is termed *the imago*.

The compound eye of insects and the silk-spinning apparatus which some possess in their larval stage require brief description.

The *compound eye* is thus formed. Two optic nerves are given off from the supra-œsophageal ganglion, each of which spreads out into a secondary ganglion. From this a vast number of exceedingly short branches are given off, which pass through an expanded pigmentary tunic, called the *common choroid*, and then themselves dilate into a nervous layer, the *common retina*. From this retina a multitude of long filaments are given off, each of which terminates in a little corneal prism, the *corneal facets*. The common house-fly possesses about 8,000 of these, each of which, from being connected with a separate nerve, constitutes a separate and perfect organ of vision: other insects possess even a greater number.

Some insects *spin silk*. The apparatus is arranged in the following manner:—Two long and large secreting cæcal tubes are situated on either side of the alimentary canal; these terminate in excretory ducts, which pass up to terminate on the under lip, at the base of a little elevation called the *fusulus*, or *spinneret*. When spinning, this fusulus is placed against any object, and the head being withdrawn, the tenacious fluid of the ducts is drawn out, this being exposed to the air, rapidly loses its fluid parts, and becomes converted into a thread of silk.

Insects are divided into two great groups, by the description of mouth which they possess.

Some possess a formidably armed mouth, provided with powerful jaws, and capable of biting, boring, tunnelling, &c. This is the *mandibulate* mouth, and is illustrated by beetles, dragon-flies, &c. The second group possesses a mouth adapted to suction; it is

arranged in the shape of a long, coiled, hollow tube, which is covered by spiral muscular fibres, running in opposite directions, and so enabling it to suck up the juices of flowers. This is the *haustellate*, or suctorial mouth. This group is illustrated by the butterfly, &c.

Two very interesting varieties of metamorphosis are met with amongst insects, called *Agamogenesis* and *Parthenogenesis*; the latter occurs in perfect females —the former in neuters. They are described by Professor Huxley. In *Parthenogenesis*, the female, *e.g.* the silkworm moth, lays fruitful eggs without any sexual intercourse. In the genera which multiply in this way the females never acquire wings. In bees a modification of this plan is met with: the queen bee (the only perfect female in the community) has coitus with a drone once in four or five years, the drone paying for the honour of her embraces with his life; the immense number of eggs she gives birth to during this period of four or five years are all impregnated by this single act of sexual intercourse. *Agamogenesis* is met with amongst the aphides. An aphis, when supplied with warmth, commences to produce, and goes on producing, for an indefinite period of time, fresh aphides, which, like their single parent, are all true neuters.

There are three kinds of insects whose *parasitism* is so interesting as to be worth mentioning:—

1. The Ichneumon is parasitic in certain caterpillars. The eggs are laid in the body of the grub, and grow up there into larvæ; the larvæ then devour their host, but do not devour his viscera or each other.

2. The Stylops is parasitic in bees. The male exists in the pupa stage within the body of the bee, whence it finally issues as a minute imago. The *female*, which appears like a shapeless bag, protrudes

a rudimentary head from the body of the bee, and in this situation is impregnated by the flying male.

3. The Sphex, a species of wasp, stings some large insect, such as a beetle, in the thoracic ganglia, and having paralysed its victim by this means, it deposits its offspring within the unresisting body of its victim, who devour the internal viscera at their leisure.

The **Annelida**, less numerous than the Arthropoda, contain the leech, the earthworm, the seamouse, the serpula, &c. Its definitional characters have been given above.

Physiological Processes of Annulosa.

Digestion.—In perfect insects the alimentary canal possesses a crop, a gullet, a stomach, large and small intestines, and a cloaca, common to it and the reproductive organs. In the larvæ of insects the alimentary canal is a simple tube, held down by a mesentery. In Myriapoda the alimentary canal is short, straight, narrow, and provided with saccular dilatations, which serve for stomachs. In Arachnida the digestive tube is still shorter; there are often four pouches appended to the stomach, and the intestine dilates before terminating.

The Crustacea have a short gullet, provided with calcareous particles which serve for teeth, and a powerful muscular apparatus which serves for a gizzard; the intestine is short, straight, and simple.

The Annelida have a straight tube provided with cæcal diverticula.

Circulation.—In the larger Annulosa, as *e. g.* in the higher Crustacea, a true heart is found, consisting of a single strong muscular ventricle, which *pumps the blood* all over the body, and is therefore

systemic. The blood is not contained in proper vessels, but is propelled into lacunæ or spaces, whence it is collected into large veins, which send it to the gills for purification; from the branchiæ the purified blood is collected by branchio-cardiac veins and poured into a venous sinus above the single ventricle, into which it passes, and so completes the circulation. In Insects we find a numerously-segmented dorsal vessel, which contracts rhythmically and propels the blood through lacunæ to every part of the body, whence it is returned into a large venous sinus placed above the dorsal vessel. In Arachnida and Myriapoda the same plan obtains, but the number of contractile segments varies widely. In Annelida there is no true contractile vessel of any kind, but certain tubes exist, called pseudo-hæmal vessels, which contain a corpusculated fluid, which circulates throughout the body, and communicates with the exterior. These tubes have close analogies to the 'water-vascular' system of Annuloida. They are always lined with cilia.

Respiration.—Many Annulosa respire atmospheric air; in others the respiration is aquatic.

Aërial respiration.—In the air-breathing Annelida small sacculi are found in each segment beneath the envelope communicating with the exterior. In Myriapoda two small hard-walled sacs are found in each segment, which communicate with the exterior by means of fine tubes called spiracles. In Arachnida a similar arrangement is met with: in some the air-sacs are tubular. In Insects the respiration is very perfect, and is what is called *tracheal.* Each segment possesses spiracles which conduct, after passing for a short distance, into two longitudinal tubes, which run the whole length of the body, and from which, secondary tubes are given off, which ramify

through every part of the body, piercing even the nervous ganglia and viscera. These tubes have firm walls and are always patent: their patency is secured by the very character of their structure. Each tracheal tube has membranous homogeneous walls, but within these walls is found a spiral thread, which is wound so closely, as itself to form a wall—these spiral threads are present in tracheæ of extreme minuteness. In the wings, we find the tracheæ placed between two sets of small vessels, one answering to arteries and the other to veins.

Aquatic respiration. — The Crustacea and the Tardigrade Arachnida are the only Annulosa which respire by means of gills or branchiæ. These branchiæ are enclosed in proper branchial cavities, and present the form of flattened laminæ. They are rather numerous in some Crustacea; *e.g.* the lobster has twenty-two branchiæ on each side. The water is kept in active motion by means of special flappers, which are made out of some of the abdominal segments.

Some of the Crustacea, such as the wood-lice and land crabs, though provided with gills, are drowned if kept in water. In these animals, the gills are merely kept wet by the moisture contained in the atmosphere.

The respiration amongst the Annelida is also aquatic. The branchiæ are either branched or tufted, and are situated sometimes on every segment of the back, as in *Nereis*, or round the head only, as is the case with *Serpula*, or more or less concealed, as in *Aphrodite*.

Nervous System.—The comparatively large supra- and sub-œsophageal ganglia give off nerves to the *eyes, to* the auditory apparatus, to the antennæ,

where the sense of touch is located, to the antennulæ, where the sense of smell resides, and sensory nerves to the entire body. These ganglia are the seats of sensation, of sensori-motor actions, and of volition. They superintend and regulate, as the brain of higher animals does, all the various movements of the body. The wonderful 'consensual' actions of bees and spiders are dependent upon these ganglia for their due performance. Small gangliated cords pass from these ganglia to the alimentary canal and viscera, which by some (Marshall) are held to be a representation of the sympathetic system, while others assert (Huxley) that the homologue of the vertebrate sympathetic system is to be found in the principal ventral gangliated cord of Annulosa. The function of this gangliated cord is automatic, and presides over the pure reflex actions of the animal.

Senses.—In the preceding two kingdoms, the organs of sense have been but poorly developed, and confined to those of sight and hearing—in Annulosa the senses are much more perfect. *The sense of touch* resides in the antennæ of some (ants), the palpi and feet of others (spiders).

The sense of taste resides in the pharynx.

The sense of smell resides in the antennæ in some, in the palpi in others.

The sense of hearing usually resides at the base of the first antennæ; in many insects a sac is found there filled with fluid, and containing otoconia.

The sense of sight is very perfect, and two kinds of eyes are found; the simple and the compound. The Orthoptera, Hemiptera, Neuroptera, and Hymenoptera have both simple and compound eyes. Some are destitute of eyes, as the neuter Termites. The simple eyes which are met with amongst

Insecta have considerable analogies to the human eye. The whole is contained in a choroidal tunic, which bends down in front to form an iris and a pupillary opening; within this we find an expanded retina, a vitreous humour, and a small globular lens; there is no anterior chamber, the lens projecting directly against the smooth convex cornea.

The compound eyes have been already described.

The eyes of Myriapoda are conglomerate, *i. e.* simple eyes massed together—and rarely compound eyes are met with; many are blind. The Arachnida have only simple eyes. The Crustacea have both simple and compound eyes. The Annelida possess ocelli only.

CHAPTER VI.

SUB-KINGDOM V.—MOLLUSCOIDA.

MOLLUSCOIDA (mollis, *soft*; εἶδος, *like*; resembling Mollusca).

Definition. Aquatic animals,—met with all over the world.

The nervous system consists of a principal ganglion near the mouth, which is sometimes surrounded by a nervous collar. There is sometimes only one opening, which answers both for inlet and outlet. When there are two apertures, the outlet is situated close to the gullet or inlet. The gullet always conducts into a very large and widely expanded pharynx: the outlet, when present, conducts likewise into a large space, called the *atrial chamber*. The trunk is (with the exception of one group, the Appendicularia) surrounded by ciliated tentacles.

They contain the following classes:

1. Ascidioida.
2. Brachiopoda.
3. Polyzoa.

Ascidioida (ἀσκός, *a bag*). Synonym, *Tunicata*. The Ascidioida are very singular-looking marine animals, resembling a double-necked little leather bottle at first sight. They frequently are grouped together in colonies, forming compound Ascidians. The gullet, surrounded by long ciliated tentacles, leads into an extremely wide and long pharynx, which occupies the greater part of the animal's body; this terminates at the lower and attached part of the body in an intestinal tube, which is

flexed towards the heart, forming a *hæmal* flexure, as it is termed; after dilating into a stomach, it is continued up the body and opens near the oral aperture into a wide cavity, the *atrial chamber*, which terminates in a prolonged excretory tube. In all Ascidians, except Appendicularia, the chief ganglion is placed between the oral and the anal apertures.

All Ascidians possess a heart, which is unique in its structure. It is a muscular tube open at both ends. It contracts rhythmically; first propelling the blood from behind forwards, then pausing, and afterwards, contracting in the opposite direction, it propels the blood from before backwards.

The covering of Ascidians is of a leathery consistence, and is secreted by a sort of mantle. They are always stationary. The integument of the Ascidians is composed of cellulose.

Brachiopoda are small bivalved marine Molluscoida: they inhabit the profound depths of ocean, and are strongly encased, to resist the great pressure of water. Like the Ascidioida they are stationary; but they never form into colonies. The shell is secreted from a true mantle or pallium. There are two long ciliated arms on either side of the body. The gullet is placed in the centre of the body between the pallial lobes, and conducts into an intestine which, as a rule, ends in a cul-de-sac. The intestine has a *neural* flexure, *i.e.* it is flexed towards the nervous ganglion. The Brachiopoda possess a singular bilocular organ, called a *pseudo-heart*, which communicates with an atrial cavity near the mouth. The true heart is placed near the pseudo-heart, and is systemic in character. Most of the Brachiopoda are fossil. The Terebratula and Lingula are the most common living species.

Polyzoa (Synonym, *Bryoza*).—This class forms the

large order of compound coralline polyps. Some are fresh-water animals, as *e. g.* Plumatella, but the majority are marine in their habits. The Polyzoa are all very minute, even to being microscopic. The mouth is surrounded by long ciliated tentacles, which, constantly moving, draw in any passing nutriment. The gullet leads into a pharynx, and this into a distinct stomach, which ends in an intestine; the intestine, making a sharp *neural* bend, ascends to terminate near the mouth. The chief ganglion is always placed between the two apertures. They multiply by gemmation and free ova. There is no distinct heart.

Physiological Processes of the Molluscoida.

Digestive System.—The Molluscoida are about the simplest animals in which a distinct alimentary canal is found, quite separate from the perivisceral cavity. In some of the Polyzoa the stomach is truly gizzard-like.

Circulatory System.—In the *Ascidioida* the heart is at one time systemic, and at another respiratory. It possesses no valves, and pumps the blood into loose spaces or lacunæ. In the compound Ascidioida the vessels of one animal are connected with those of another through the common foot-stalk or 'stolon.' In the Brachiopoda the heart only contracts in one direction. The pseudo-heart of Brachiopoda is excretory in its function. The Polyzoa possess no distinct circulatory system.

Respiratory System.—In the Ascidioida the large pharynx is ciliated, and acts as a respiratory organ. It is separated from the exterior of the animal by a perivisceral space: this space has slit-like openings into it passing from the outside; through these

apertures the water is admitted, holding oxygen in solution, and this easily passes by dialysis into the vessels of the pharynx, and so aërates the blood. In Brachiopoda the pallial lobes are the respiratory agents. In *Polyzoa* the perivisceral cavity is continued into the interior of the tentacles, where the blood is purified by the ciliary action which here takes place.

Nervous System.—The chief ganglion, which is the homologue of the pedal ganglion of Mollusca, sends filaments to the ciliated pharynx, and to the ciliated tentacles. Sometimes an eye-spot is developed on a filament which proceeds from it. The Molluscoida being nearly all stationary, the functions of this ganglion are of a reflex character, and have reference to respiration. It is also feebly sensory, and sensori-motor.

CHAPTER VII.

SUB-KINGDOM VI.—MOLLUSCA.

MOLLUSCA (mollis, *soft*). Synonym, *Heterogangliata* (Owen).

Definition.—This very large sub-kingdom is composed of animals of very various and irregular shapes, whose envelope is soft, but generally protected by a shell. The shell is secreted by the integumental covering which is termed the *mantle*. The nervous system is massed into three principal ganglia. One is situated in the head, another in the abdomen, and a third in the fleshy locomotive organ called the *foot*. These ganglia are termed respectively the *cerebral*, *parieto-splanchnic*, and *pedal* ganglia. The gullet is surrounded by a nervous collar, and commissural cords connect the cerebral and pedal ganglia. The heart is systemic, and consists of two cavities; the blood is contained in tubes. Except in the highest Mollusca there is no trace of an internal skeleton. The body is not segmented. They are developed from eggs.

The Mollusca are divided into two great groups, before they are broken up into classes. These two groups are the *Odontophora* and the *Lamellibranchiata*.

The *Odontophora* (*ὀδούς, a tooth*; *φέρω, I bear*) are classes of Mollusca armed with teeth and a long tongue-like organ, which serves the purpose of a tooth, called the odontophore.

The *Lamelli-branchiata* (lamella, *a thin plate*; *βράγχια, gills*) are Mollusca provided with a

bivalve shell, and between the two shells we find two thin vascular leaves on either side, which serve for respiratory organs.

The *Odontophora* contain the following classes :—

1. Branchio-gasteropoda (*βράγχια, gills*; *γαστήρ, belly*; *ποῦς, a foot*).
2. Pulmo-gasteropoda (pulmo, *lung*; *γαστήρ, ποῦς*).
3. Pteropoda (*πτέρον, a wing, ποῦς*).
4. Cephalopoda (*κεφαλή, a head, ποῦς*).

The *Lamelli-branchiata* contain themselves alone.

Branchio-gasteropoda include whelks, periwinkles, and sea-slugs. The mantle secretes a shell which is often univalve, sometime multivalve, but never bivalve. The odontophore is attached to two 'cartilaginous cushions,' over which it is worked by muscles in a pulley-like manner. The odontophore is studded with teeth, which are constantly being renewed. The alimentary canal takes a *hœmal* flexure. The Branchio-gasteropoda respire either by means of the thin mouth, or by gills developed from the mouth, or by the soft integument itself.

Pulmo-gasteropoda include the slugs and snails. The alimentary canal performs a *neural* flexure. They respire by lungs.

Pteropoda are minute marine Mollusca. The foot is placed close to the head, and is divided into three parts; the upper are very much more largely developed than the other two, and serve the purpose of aquatic wings.

Cephalopoda include cuttle-fish, poulpes, the nautilus, and many fossil forms of ammonites and belemnites. In many respects the Cephalopoda crown the Invertebrate kingdom. There is a distinct head; their organs of sense are very thoroughly developed; they possess traces of an internal skeleton; their organs of locomotion are powerful. Cephalopoda

are always provided with a parrot-like mouth, composed of two horny curved pieces, which move in an antero-posterior median plane. The foot is singularly modified. It is divided into segments, which are much prolonged and form eight 'arms'—each arm is furnished with a vast number of fleshy discs, which act as cupping glasses and constitute efficient prehensile organs, and powerful weapons of attack. The head, furnished with two large and prominent eyes, is placed in the centre of these arms. The intestine presents a *neural* flexure.

Lamelli-branchiata (Synonym, *Conchifera*) include all bivalve Mollusca, except Brachiopoda; consequently, mussels, cockles, oysters, scallops, &c., are found in this extensive class. The shells of Lamelli-branchiata are always *right* and *left*, never anterior and posterior, as in Brachiopoda. The valves of the shell are secreted by a pallium or mantle. The valves can be approximated by one or more adductor muscles.

Physiological Processes of Mollusca.

The high degree of development in the internal organs of Mollusca induced Cuvier to rank them at the top of the Invertebrate scale. We have to examine into the processes of Digestion, Circulation, Respiration, Locomotion, and the Nervous System.

Digestion.—The first thing that strikes us in the digestive system of Mollusca is the similarity which it bears to that of birds. In both (as a rule) we find a crop, a gizzard, and true digestive stomach, the difference being that in birds, the digestive stomach (the proventriculus) is placed before the gizzard, while in the Mollusca the gizzard is placed before the digestive stomach.

The *Cephalopoda* possess prehensile organs in the tentacles which surround the mouth; most other Mollusca depend upon ciliary action for the conveyance of their food, others have no prehensile organs but their mouths.

The *Cephalopoda* have parrot-like beaks, which open and shut vertically. All other Mollusca, except Lamelli-branchiata, are furnished with an organ which serves the purpose of a masticatory apparatus. This organ, situated in the roof of the mouth, was formerly called a tongue, but now is known as the odontophore; it is a strap-like organ beset with teeth, and worked in a rasping file-like manner by muscular action.

The buccal cavity in all Mollusca opens at once into the œsophagus, which dilates often into a crop; below the crop we find a strong muscular bag, the gizzard, which, in the most perfectly developed Mollusca, the Cephalopoda, is furnished with two lateral digastric muscles; there is another expansion below the gizzard, which represents the true digestive stomach; the intestine is long in vegetable feeders, short in animal-feeders, particularly in the Lamelli-branchiata. There is no distinction into large and small intestine.

Cephalopoda, Pteropoda, and Gasteropoda, are all furnished about the mouth with a salivary gland.

The liver is very large in all Mollusca. It is solid, lobulated, and has two ducts. There is never a portal *venous* system in any Invertebrate. In some Cephalopoda and Branchio-gasteropoda an organ resembling a pancreas exists.

Circulation.—The heart of Mollusca is either single or double; it is always systemic in character. In aquatic Mollusca the circulation is carried on as follows:—The blood, like the blood of all Invertebrates, is not coloured with cruorin, but is either

colourless or has a greenish tinge; it is however corpusculated. This blood is propelled by a strong muscular ventricle through tubes to every part of the body, except the gills; from all these parts it passes, directly and without the intervention of capillaries, into returning channels or veins; these veins then pass to the gills, and present in the higher forms distinct pulsatile cavities, known as branchial hearts, which propel the blood throughout the gills, where it is purified; it is then returned by branchio-cardiac veins, either directly to the ventricle, as in Pteropoda and Lamelli-branchiata generally, or by the intervention of an auricle, as in Gasteropoda and Cephalopoda. The blood is not contained entirely in vessels, but is pumped into lacunæ, or spaces, whence it is re-collected into vessels. In the terrestrial Mollusca the heart is also single and systemic, but the blood instead of being collected into branchial veins is collected into vessels which ramify over the pulmonary air-sac, and purify it there; thence it is returned into an arterial auricle placed above and separated from the right ventricle by a valve.

Respiration.—Most Mollusca are aquatic and respire by branchiæ. In many these are ciliated, *e.g.* Pteropoda, Branchio-gasteropoda, except in some of the lowest, which are supposed to respire by their surface only; in others the gills are non-ciliated, *e.g.* Cephalopoda. The position of the respiratory organs is various.

Some Mollusca (Pulmo-gasteropoda) are terrestrial and respire by air-sacs. The air-sac communicates with the external air by an aperture on the left side of the neck, and is placed within the mouth and the smaller coils of the shell. It is hollow, ciliated, and abundantly supplied with blood.*

* Vide page 97.

System.—The three principal ganglia pedal, and parieto-splanchnic, have each functions of their own. The *cephalic*, of the vertebrate brain, is the centre of motor actions—it even exercises a weak power over the rest, as seen in the search The other ganglia are brought into connection by nerves. All the organs of sense, except hearing, receive nerves directly from the ganglion; the organ of hearing is supplied by the with the cephalic ganglion. The *pedal* ganglia the centres of the reflex excito-motor actions, and therefore are representatives of the vertebrate spinal cord. The *parieto-splanchnic* ganglia the centres which preside over organic life, plying the branchia, the heart, and the digestive tem, and may therefore be looked on as representatives of the sympathetic system.

Senses.—Organs of smell, sight, and hearing exist all Mollusca.

Smell.—In the Cephalopoda the organs of smell are two small cavities, placed near the back of the eye—they each receive a twig from the side of the optic nerve. In the other Mollusca the sense of smell resides in the sensitive tentacula found at the entrance to the mouth.

Sight.—The organs of sight, which are very perfect in Cephalopoda, become gradually simplified as they descend the Molluscous classes. In Cephalopoda the eyes are very large, and connected by optic nerves to the cephalic ganglion. There is no anterior chamber, but with this exception, the tunics and humours resemble those in man; the lens is dense, and projects into the water. There is no circular *iris* and ciliary processes.

All the remaining Odontophora have eyes. In the Pteropoda they are shaped like a bent cylinder. In the Pulmo- and Branchio-gasteropoda they are numerous black points, each consisting of a transparent elevation of the soft skin of the tentacle, a globular lens, a choroid with an iritic opening, and an optic nerve expanding into retinal elements.

Many *Lamelli-branchiata* are eyeless; in some however, as *e.g. Pecten*, eye-spots exist, which are situated at the free edge of the mouth, projecting between the valves.

Hearing.—All Molluscous classes possess organs of hearing. They are composed of cavities filled with a gelatinous fluid, and containing cretaceous otoliths; the sacs are always in close connection with the auditory nerves, which either spring from the sub-œsophageal cephalic ganglion, as in Cephalopoda, &c., or from the pedal ganglion, as in most of the remaining Mollusca.

The Growth of Shells.—Shells are secreted by the pallial covering or mantle of the mollusc. The shell extends in size by a secretion poured out from the free edge of the mantle, and therefore grows as the mantle increases. This part of the mantle is thick and glandular and mixed with pigment-cells. The shell material is poured out, mixed with the pigment, in a semifluid state, which rapidly dries and hardens into shell on exposure to the air. The shell increases in thickness by a secretion poured out from the general surface of the mantle, and as there are no pigment-cells in this situation, the inner surface of the shell is perfectly white and pearly or nacreous. Some shells become spiral, because the collar, or free edge of the mantle, pours out its secretion much more from one part of its circumference than another, and the *fact* that sometimes one part and sometimes

another becomes the actively-secreting par
mantle accounts for all the infinite variety o
which are met with amongst the shells of M
The principal ingredient of *shell* is carb
lime, of *bone*, phosphate of lime.

CHAPTER VIII.

SUB-KINGDOM VERTEBRATA.

Definition.—Animals that possess a vertebral column, formed by the coalescence of vertebræ; or, more universally, animals that possess at some period of their existence a fibro-cellular rod tapering to either end, and situated in the site of the future vertebral bodies, when they exist, and called the *notochord*. All Vertebrata do not possess limbs; when they do, they never exceed two pairs. The skeleton which gives attachment to the muscles is always *internal*. The heart contains red corpusculated blood, and is composed of two or more cavities. A portal *venous* system is always present. The *respiratory organ* communicates with the pharynx. The *alimentary canal* is always provided with a distinct inlet and an outlet. The *nervous system* is much more largely developed than in the highest of the Invertebrata; it is lodged in the vertebral column and in its expanded upper portion, termed the cranium, and consists of a brain and spinal cord.

A vertebra, the coalescence of which makes up the column, is formed of the following parts: There is, in the first place, a central mass called *the body* or *centrum*, from which extends an upper and a lower bony arch; the upper arch lodges the nervous system and is called the *neural* arch, the lower arch protects the vascular system and is called the hæmal arch; a spinous process, called respectively the

neural and the *hæmal spinous process*, is appended to the extremities of their respective arches. Vertebrata are subdivided into the five following classes: *Pisces—Amphibia—Reptilia—Aves—Mammalia.*

Pisces.

Definition.—Pisces live in water, and breathe by means of gills. The heart consists of two cavities only, and is respiratory in character. An auricle receives the impure blood of the body and propels it into the ventricle, whence it is pumped through a vessel which divides into four or five branches, to the gills; here it is purified by being brought into contact with the oxygen dissolved in, but not chemically combined with, the water, and being re-collected by the branchial veins, it is poured by their convergence into a large vessel which runs along the dorsal aspect of the alimentary canal, and corresponds to the aorta; by this it is transmitted to the entire body, except the gills. The body is covered with scales. The limbs are modified into fins. The primordial renal organs, corpora Wolffiana, persist through life. The kidneys are not divisible into cortical and medullary portions, but consist of cortical substance only; the ureters open into a cloaca common to themselves and the rectum. The kidneys receive a supply of venous blood, just as the liver does. The cerebral part of the nervous system is but slightly developed, and affords a clue to the plan of construction of the vertebrate brain. It is arranged as an antero-posterior chain of ganglia, called from before backwards, *rhinencephalon*, *prosencephalon*, *mesencephalon*, and *epencephalon*. Each occupies a distinct portion of the cranium, which consists, in deed, *of four* modified vertebræ: the most anterior

containing the *rhinencephalon*, is the *cranial-nasal-vertebra*; the next, containing the *prosencephalon*, is the *frontal vertebra*; the third, containing the *mesencephalon*, is the *parietal vertebra*; and the fourth, containing the *epencephalon*, is the *occipital vertebra*. We are able to discover, from the simple character of fishes' brains, the true arrangement of the elements of the brains of all vertebrate animals, whose brains differ from each other solely by the greater comparative development of one or another of their cerebral ganglia. The first pair of ganglia compose the *olfactory lobes*, the second constitute the *cerebral hemispheres* (or their earliest and most constant elements, the *corpora striata*), the third are the *optic lobes*, and the fourth compose the bilaterally symmetrical *medulla oblongata*, upon which rests a single lobe, the representative of the *cerebellum*. No external organ of hearing or tympanum exists, but a vestibule and semicircular canals are present. A lymphatic and lacteal system exists in all fishes except Amphioxus. The lymphatics are not very numerous, but contractile dilatations exist in connection with the jugular vein in many fishes, which are termed 'lymphatic hearts.'

Besides the modified limbs which form the pectoral and ventral fins, and which are always double, there are median single fins, forming the dorsal and anal fins, and which are probably developed from the exo-skeleton. They always consist of two sets of bones, *interspinous bones*, which articulate with the neural and hæmal spines, and *fin rays*, which are connected with the extremities of the former.

The nostrils form (except in Lepidosiren and the Myxinoids) culs-de-sac, not communicating with the pharynx.

Physiological Processes of Pisces.

Digestion.—The jaws are the only organs of prehension which a fish possesses. To render them as efficient as possible, both jaws are moveable, and capable of protrusion and retraction, as well as of opening and shutting. The teeth of fishes are almost infinitely various in number and shape. The myxine or hag-fish has but one tooth, with which it eats its way into the vitals of its victim. The pipe-fish, the sturgeon, and others, are quite toothless. The tench has powerful pharyngeal teeth, *i. e.* situated in and about the pharynx, and one tooth on the occipital bone. In the shark family they are exceedingly numerous, row behind row, and are still more numerous in the pike tribe. The teeth are placed on most of the bones about the head, often studding not only the premaxillary and dentary bones, but the vomer, the basi-occipital and basi-sphenoid, the hyoidean arches, the super-maxilla, the pharynx, pterygoid, sphenoid, nasal bones, and branchial arches. They are very generally anchylosed to the bone, but in some fishes, as in the lophius, and some sharks, they are attached by means of elastic ligaments, which will allow them to be bent backwards towards the gullet, but the pressure being removed enables them to spring into position again. In structure they are often composed of dentine only; but in the diodons, and some sharks, teeth are met with composed of enamel, cement, dentine, and osteo-dentine. In shape they are most often conical, sometimes lancet-shaped, as in the barracuda; sometimes flattened at the top and arranged like a mosaic pavement, as in the Portland shark; sometimes *notched at the sides*, as in the majority of the shark family; *sometimes* cuneiform, as in the parrot fish,

A pharynx, as has already been intimated, is peculiar to the Vertebrata, and is therefore first met with in fishes. In this class it is short, does not communicate with the nasal passages, and leads into a short œsophagus. The œsophagus leads into a true digestive stomach, which is sometimes guarded by a cardiac as well as by a pyloric valve. The intestine is wide and short, the difference between large and small being only indicated by a slight constriction; there is no ileo-cæcal valve. In the shark, and some other fish, the digestive surface is increased by means of a spiral fold of mucous membrane being wound round the interior of the gut from pylorus to anus. The liver is large. Connected with the stomach are certain diverticula, like the fingers of a glove, numerous in some, as in the salmon, few in others, as in the perch, called *appendices pyloricæ*; these are probably homologous in action to the pancreas.

Circulation.—The heart of fishes is contained within the bones of the head; there is no true diaphragm to separate thorax from abdomen. The heart consists of two cavities. Its action has been described. The amphioxus does not possess a true contractile heart, but numerous contractile cavities containing colourless corpuscles situated in the course of the chief blood-vessels.

Respiration.—Water, containing oxygen in a state of solution, is taken into the mouth, and thence passed through the branchial arches, and so comes into contact with the blood contained in the branchial capillaries, which rob it of its oxygen. In addition to the gills, however, an additional respiratory organ exists in most fishes, called the *swimming bladder.* This is a hollow musculo-membranous sac, situated close to the vertebral column, and

often connected by a small tube, the *ductus pneumaticus*, with the œsophagus or pharynx. It is covered by 'retia mirabilia' of blood-vessels, and contains air, which can be renewed, compressed, or expelled. It serves both to assist in purifying the blood and to lighten the body of the fish. Flat-fish and sharks do not possess a swimming-bladder. It also probably serves, from its occasional connection with the internal ear, as an acoustic organ, and increases the vibration of sound.

Nervous System.—The encephalon is arranged, as has already been said, as an antero-posterior chain of four symmetrical ganglia. The cerebral hemispheres merely form a thin grey coating, which covers the second pair of ganglia, the representatives of the corpora striata. The third pair, or optic lobes, are the largest of all, in fishes. The two halves of the medulla are more or less separated by an interval. There is no pons Varolii. The cerebellum consists of a median portion only, evidently the homologue of the vermiform process. The cranial nerves are all present except the ninth. The fifth is large, and sends a considerable branch, the *great lateral nerve*, to supply all the muscles (called myocommas) on the sides of the fish. The pneumogastric supplies the gills.

The sympathetic system resembles that of man.

Even in this, the lowest Vertebrate class, the nervous system is endowed with volition, as well as excito-motor and sensori-motor powers.

Senses.

Touch.—The folds of membrane in front of the mouth, which serve for lips, the soft parts about the mouth, and occasionally the pectoral fins, are all liberally supplied with nerves, and possess tactile corpuscles; they are therefore all regarded as organs of touch.

Taste.—The tongue is little developed in fishes,

and is never protrudible beyond the mouth. It serves more as an organ of deglutition than of taste. The sense of taste, indeed, is scarcely at all present.

Smell.—The olfactory nerves, which continue the olfactory lobes to the nasal sac or sacs, are rounded cords, and do not divide into filaments. They are distributed to the delicate membrane of the nasal sacs. Sometimes the membrane is plicated. In the myxinoids and the lepidosirens a tube establishes a communication between the palate and the nasal sacs.

Hearing.—The vestibule, and two or three imperfectly developed semicircular canals, are the only parts of the organ of hearing which exist in fishes. The vestibule always contains an otolith or two, situated in a utricle and saccule. No organ of hearing exists in the amphioxus, which is the lowest of the fish class.

Sight.—The eyes and orbits of fishes are large. The eyeball is more or less flattened; the sclerotic is very thick; the lens is spherical and brought close to the cornea; all which modifications must tend to bring the luminous rays very soon to a focus, and adapt the animal to see accurately objects at a short distance. In addition to the ordinary tissues and humours, the choroid contains between its layers a vasculo-pigmentary structure, of a horse-shoe shape, called the 'choroid gland.' Sometimes, *e.g.* in the sturgeon, this develops a process which passes towards the lens; this process is called the 'campanula.' The optic nerve is also peculiar in being folded upon itself, like a lady's fan. In flat fishes, which lie on their side, both eyes are situated on the same side of the head. In the anableps each pupil is divided into two by a vertical septum, forming a natural stereoscope. Fishes possess neither lachrymal glands nor lachrymal passages or eyelids.

Electric Organs.—Eight species of fish possess electric organs: viz. three are torpedoes, belonging to the ray family; the fourth is the sword-fish; the fifth is the tetraodon; the sixth is the silurus; the seventh is the momyrus; and the eighth, and by far the most powerfully armed of all, is the gymnotus, or electric eel.

The electric organs are composed of cells, generally hexagonal, having very large nerves connected with them. One end, or surface, as the case may be, of the animal, is positive in its electricity, the other is negative. If the nerves are cut the electrical power is at once abrogated. The cells contain an albuminous fluid, sp. gr. 1026.

The class Pisces was divided by Agassiz into four orders, arranged according to the construction of their scales. He divided them into Ctenoid, Cycloid, Placoid, and Ganoid.

1. *Ctenoid* (κτείς, *a comb*) comprised all fishes whose scales are provided with a fringe-like border, *e.g.* the sole.

2. *Cycloid* (κύκλος, *a circle*) comprised fishes whose scales are arranged in concentric rings and with smooth edges, *e.g.* the dace.

3. *Placoid* (πλάξ, *a flat plate*) comprised fish with a flat integument, which however is frequently studded with tubercles, *e.g.* the shark.

4. *Ganoid* (γάνος, *brightness*) comprised fish with a sort of mosaic plated bony armour. Only two representatives now remain of this order, the lepidosteus and the polypterus.

Amphibia (*Batrachia*, Cuvier).

Definition.—Cold-blood vertebrates that breathe *by means of* branchiæ during some period of their

existence, but possess lungs as well, sooner or later. Some possess median cutaneous fringes, but never *fin rays*. The skull articulates with the spine by two condyles. The basi-occipital is always cartilaginous.

The nasal sacs communicate with the pharynx.

Some amphibia retain their gills through the whole of their life: these are called *Perenni-branchiata*, and comprise the proteus, siren, and axolotl; others lose their gills after a time, and breathe by lungs only; these are called *Caduci-branchiata*, and comprise frogs, toads, and newts. The metamorphoses which the aquatic-breathing tadpole passes through in becoming changed into the aërial-breathing frog are as follows: The tadpole is, to all intents and purposes, a fish, unpossessed of limbs, but provided with four vascular ciliated plates or branchiæ. There is no tongue. The intestine is a close double spiral tube, adapted by its length and complexity to assimilate the vegetable food which forms its pabulum.

As soon as the gills are thoroughly developed, the lungs commence as simple elongated sacs, which project backwards into the abdominal cavity; they develop as the gills dwindle and shrink away. The intestine becomes shorter, straighter, and much wider, fitting the animal for a carnivorous diet. A tongue and well-formed teeth make their appearance. The upper and lower jaws become ossified. The limbs become gradually developed, the fore legs first, and finally exhibit all the bones, in an easily recognisable way, which are present in the human limbs. As soon as these changes are complete the tail drops off, and the animal respires air only; in other words, changes from a tadpole to a frog.

Amphibia possess a larynx and are endowed with *powers* of vocalization.

Physiological Processes of Amphibia.

Digestion.—The changes from the phytophagous tadpole to the carnivorous frog have been spoken of. There is no ileo-cæcal valve.

Circulation.—In the *Caduci-branchiata* the circulation changes from that of a fish to that of a reptile. The heart at first consists of a single auricle and a single ventricle; the ventricle forces the blood into the dilated commencement, called 'bulbus arteriosus,' of a large artery; this transmits it by four vascular arches to the gills, which, at first *external*, have given place to four *internal* laminated plates. From the gills it is collected by branchial veins and poured into a large dorsal vessel, which transmits it to every part of the body. As the animal gradually changes from a water-breathing to an air-breathing creature, these vascular arches change too; from each arch small vessels pass directly down and empty their contents into the descending aorta; these enlarge until all the blood enters them; the upper three constitute permanent channels, connecting the bulbus arteriosus and descending aorta; the fourth or lowest becomes the pulmonary artery as the lungs develop; the blood is returned from the lungs by pulmonary veins, which enter a superadded auricle, from which it is poured into the single ventricle. In some cases there is a partial septum developed in the ventricle, so far as to foreshadow the perfectly four-chambered heart of birds and mammals. In the *Perenni-branchiata*, the three upper vascular arches continue through life to supply blood to the gills; the fourth becomes the pulmonary artery as in the former instance.

Absorption.—The lymphatics are few in number, *large in size*, and unprovided with valves. Lymphatic hearts, which possess unstriped muscular

walls, and contract rhythmically, but not synchronously, with the heart, are present. In the frog there are four of these hearts—two in the neck and two in the pelvis.

Respiration.—The Perenni-branchiata always respire both by lungs and gills. Their gills are *external* and *plumose*, and always *ciliated*; they project freely into the water. The Caduci-branchiata breathe for a short time only by external gills; these give place to internal gills, placed in a branchial chamber, and homologous to the gills of fishes; these finally give place to lungs. The lunged *Caduci-branchiata* swallow air; it is first collected into a sort of musculo-membranous bag connected with the hyoid bone; the nostrils are then closed, and the air forced by muscular contraction of this sac into the lungs. The *Caduci-branchiata* also respire by their skin.

Nervous system is in the lowest Amphibia (Perenni-branchiata) essentially the same as in fish; in the highest Amphibia (Caduci-branchiata) essentially the same as in Reptilia.

Senses.

Touch is much more perfect than in fish; the lips, the limbs, and the general soft skin all being seats of the sense of touch.

Taste.—The tongue is generally a prehensile organ rather than an organ of taste.

Smell.—There are two posterior nares communicating with the pharynx. This sense is more highly developed than in fishes.

Hearing. — Still neither external ear nor true cochlea exists, but vestibule and three semicircular canals with otoliths and perilymph. A tympanic cavity and Eustachian tubes exist in a few, e.g. in *frogs.*

Sight.—There are eyelids, but still no lachrymal apparatus. The frog has no oblique muscles. A *membrana nictitans* is present. The other parts of the eye resemble the same organ in fish.

Reptilia.

Definition.—Cold-blooded Vertebrata that respire by means of lungs.

The lungs are imperfectly cellular, and are situated in a common thoracico-abdominal cavity. The heart is three-chambered, containing two auricles, and one ventricle, which is sometimes imperfectly divided by a median septum. The skull articulates with the spine by means of a single condyle. The basi-occipital is ossified. The lower jaw does not articulate directly with the skull, but is separated from it by means of a strong bone, the *os quadratum*.

Reptilia are divided into four living and several extinct orders. The four living orders differ so widely from each other as to require separate definition.

1. *Crocodilia* — comprising crocodiles, alligators, and caymans—constitute the most typically perfect of all vertebrate skeletons. A crocodile (*e. g.*) exhibits four cranial vertebræ, seven cervical, thirteen dorsal, two or three lumbar, two sacral, and about thirty caudal vertebræ, in most of which a neural and a hæmal arch can be made out, with the usual processes and appendages. They possess no clavicles, a circumstance that may almost always be predicated of animals with prone limbs. False ribs are developed from the front of the abdomen, which have their homologues in the transverse striæ of the human rectus. The ventricular septum is so nearly complete, as *to render the* heart almost perfectly four-chambered.

2. *Lacertilia* — comprising chameleons, blind-worms, and lizards — are distinguished from the other classes by possessing clavicles, and their teeth not being lodged in sockets, as is the case in crocodilia. The heart is three-chambered.

3. *Ophidia* include the snakes. They have no limbs whatever, nor scapular or pelvic arch, or hæmal thoracic arch; they possess, however, vast quantities of ribs. The rami of the mandible, or lower jaw, are united only by ligament, and each half can be separately protruded or retracted; this symphysial joint, together with the large moveable quadrate bone, which separates the mandible from the skull, enables the ophidian to open his mouth in every direction to a prodigious extent. The heart is three-chambered.

4. *Chelonia*—comprise the turtles and tortoises. The strong bony box, which forms the chief part of the skeleton, appears *primâ facie* to be exo-skeletal, but is really formed from elements of the dorsal vertebræ. The dorsal plate, called the *carapace*, is formed by the flattening and broadening-out of the neural spines of the dorsal vertebræ; the ventral plate, called the *plastron*, is formed by the fusion of the broadened and flattened elements of the hæmal arch: namely, the pleurapophyses or ribs, and the hæmal spines or sternal elements. The limbs are well developed. The heart is three-chambered.

The extinct orders are the Ichthyosauria, Plesiosauria, Dicynodontia, Pterosauria, and Dinosauria.

Physiological Processes of Reptilia.

Prehension of food, Deglutition, and Digestion.— The four orders of Reptilia differ from each other

in their prehensile and digestive organs. The Crocodilia employ their jaws as prehensile organs. Both upper and lower jaws are studded with numerous conical teeth, averaging about thirty, composed of dentine, with sometimes a thin coating of enamel. They are lodged in sockets, and are perpetually renewed from a vascular papilla at the base: this constantly producing new teeth, it comes to pass that they grow one within the other, causing absorption of the interior of the older teeth, and becoming nested, like a series of pill boxes. The tongue is large and fleshy, but not protrudible beyond the jaws. The passage into the larynx and œsophagus is closed at will by a strong musculo-membranous valve, one fold dropping as a continuation from the soft palate, the other rising from the hyoid bone. The nostrils are at the very tip of the snout, so that the crocodile can hold his mouth under water, frequently containing a living struggling prey, and at the same time breathe with perfect ease (as the nostrils lead *behind* the flood-gate) so long as merely the tip of his snout projects above the water.

Crocodilia are carnivorous; and in consequence the alimentary canal is comparatively short and simple. It is interesting from the resemblance it bears to that of birds. A short œsophagus leads into an almost circular and gizzard-like stomach, so strong are the two lateral muscles which compose its walls; the pyloric aperture, guarded by a valve, is placed near the cardiac extremity; the succeeding intestine is short; the junction of small and great gut being marked by the presence of an ileo-colic valve, but no cæcum; it opens into a cloaca common to it, and the urinary and generative organs.

Lacertilia.—The chameleons employ their long *muscular clubbed* tongue as the chief prehensile

organ. The lizards generally use their jaws. The teeth are small, and composed of dentine, cement, and enamel; the alimentary canal approximates that of the Crocodilia.

Ophidia.—Constricting snakes employ the folds of their body as assistant prehensile organs to the simple, numerous recurved teeth which stud, not only the dentary and premaxillary bones, but the ptergyoid and superior maxillary bones also. The poisonous snakes possess, instead of teeth on the upper jaw, two poison fangs, which are anchylosed to the superior maxilla, and connected by their base with the interior of the poison bag, which occupies the temporal fossa, and whose secretion is poured out, when the mouth is widely opened, by the action of the external pterygoid and temporal muscles which cover it. The poison flows down a groove in the tooth, formed by the projection and overlapping of two of its edges; it opens a short distance from the point, so that the fang must be well implanted before the poison can enter the victim. They are so much recurved as to lie flat against the roof of the jaw when the mouth is closed; they are lodged in a sort of scabbard of mucous membrane, and are constantly renewed, when lost, by a vascular dental pulp situated *en arrière*. All the viscera, the alimentary canal amongst others, present the same elongated character as does the body of the snake. The canal is short and wide.

Chelonia capture their prey with their jaws, which are edentulous and horny, like the beak of a bird. Chelonia are phytophagous, and the alimentary canal is long and complex in consequence; for convenience of stowage it is arranged generally in a *transverse* direction. Both an ileo-colic valve and cæcum are

present. The œsophagus has large recurved epithelial papillæ, which entangle the slippery fuci which form their food, and breaking it off, assist the jaws as manducatory organs. Both stomach and intestines are notably muscular.

The salivary glands are large and abundant in Reptilia, especially so in Ophidia. A liver and gall-bladder are present in all.

The lymphatics are well developed, and lymphatic hearts are present in the neck of certain Ophidia.

Circulation.—The heart is three-chambered, consisting of two auricles, and one ventricle which distributes a mixed blood to the lungs and to the body. In the lower reptiles the ventricle is quite simple, but gives rise both to a pulmonary artery and aorta; in the higher reptiles a ventricular septum exists, which pretty efficiently keeps the venous and arterial blood separate. In the higher reptiles there are two aortic arches, a right and a left—the right being the larger—which arch over the roots of their respective lungs and meet in front of the vertebral column, to supply the hind parts of the body. In the lower reptiles there are three aortic arches on either side, the two upper of which give off branches to the head and neck; the lower give off the pulmonary arteries; finally all unite to form the abdominal aorta.

Respiration.—No reptiles, except the crocodile, exhibit the slightest trace of a diaphragm; all swallow the air, much as the frog does. In Crocodilia and Lacertilia the moveable ribs and sternum assist the respiratory movements; in Ophidia there are nothing but ribs, and expiration is partly the result of the resiliency of the lungs; in Chelonia the movements exactly resemble those of the frog; for though ribs and sternum both exist, they are perfectly fixed. The *lungs are large,* frequently unsymmetrical (in Ophidia

only one is fully developed), and saccular, or imperfectly cellular. The trachea does not branch into bronchial tubes throughout the interior of the lungs, but ends abruptly in their substance, so that the air is renewed but slowly and imperfectly.

Renal organs.—The kidneys are large, and pour their contents into two ureters, which open into the common cloaca. There is no urinary bladder. The kidneys, as in all Vertebrata below Mammalia, consist of cortical substance only.

Nervous system.—The olfactory lobes are uncovered in front; the optic lobes, which are *bigeminal*, as in fish, are uncovered behind the cerebral hemispheres. The medulla oblongata supports a cerebellum, which still consists merely of a median portion. The cerebral hemispheres are hollow, exhibiting the first trace of lateral ventricles. The optic lobes likewise contain a cavity in their interior. The cerebral hemispheres are now, however, the largest of all the cerebral ganglia. A ninth nerve is present.

Senses.

Touch is but ill developed; but the varieties of the tegumental growths are great. The osseous plates of the crocodile, the scutes (the principal organs of locomotion) of the Ophidia, the granular coat of the chameleon, the horny coverings of the plastron and carapace of Chelonia, are all developments of the cutis.

Taste.—The bifid tongue of Ophidia, the long, worm-like tongue of the chameleon, and the freely moveable tongue of Chelonia, are all rather tactile organs than instruments applied to discriminate sapid substances; the sense of taste, indeed, is scarcely at all developed.

Smell.—The mucous membrane of the nose is plicated, but this sense is imperfect. In Crocodilia

and Lacertilia the nostrils open into the pharynx; in Ophidia and Chelonia, into the mouth.

Hearing.—All reptiles, except Ophidia, possess a tympanic cavity with ossicles, in which we recognise an incus, malleus, and stapes, a membrana tympani, and Eustachian tube. Ophidia merely possess a single ossicle, the columella, which is embedded in the flesh. The internal ear presents to us now, in addition to a vestibule and three semicircular canals, a rudimentary cochlea, in the shape of a bent tube, imperfectly divided by a median partition into a scala vestibuli and a scala tympani.

Sight.—The tunics and humours resemble those in man. There are no eyelids in Ophidia, the skin being continued over the cornea. All other reptiles possess them. A lachrymal apparatus is always present, which, in the crocodile, subserves a hypocritical purpose.

Aves.

Definition.—Warm-blooded Vertebrata, clothed with feathers.

The skull articulates with the spine by a single condyle. The basi-occipital bone is ossified. The vertebral column is divided into five very distinct portions—cranial, cervical, dorsal, lumbar, and sacral. The cranial vertebræ are early anchylosed, and it is only in the skull of the young bird (*e.g.* the ostrich) that the separate bones can be made out. The lower jaw is joined to the skull by the intervention of the os quadratum, as in Reptilia. The jaws are never provided with teeth. The cervical vertebræ vary in number from nine in the sparrow to twenty-three in the swallow; they are freely moveable on each other, and permit the head to be turned in every direction for prehensile purposes. The dorsal vertebræ are

firmly anchylosed together to give stability to the great muscles, the agents in flight, which take their origin here. The hæmal arch is entirely bony, and the sternum presents a strong median ridge, or keel, which vastly increases the surface of origin of the pectoral muscles. In a few birds, the cursorial or running order, the keel is absent from the sternum. The lumbar and sacral vertebræ are few but strong; the caudal vertebræ are rudimentary, and do not give attachment to the tail feathers. In an extinct bird of the mesozoic period, the archeopteryx, the vertebral column is terminated by a veritable tail of caudal vertebræ.

The fore limbs of birds constitute the wings. We find here the scapular arch, and the bones of the arm, forearm, and claw. The scapular arch is composed of a *coracoid bone*, which is the strongest and longest bone of them all, reaching from the sternum to the scapula; a long and slender *scapula*, broader, however, in the penguin tribe than in other birds, and a *clavicle*, which, with its fellow of the opposite side, constitutes the funny bone, or 'os furculum.' The clavicle is the most variable of all the bones of the shoulder, being long and strong in the Raptorial birds, and even entirely absent in the ground parrots of Australia. The humerus is long, strong, and generally pneumatic. Of the two bones of the forearm the radius is always the slenderer bone, the ulna articulates with the scaphoid and semilunar bones, and two sets of metacarpal bones and phalanges make up the claw. The pelvic arch is strong and firmly knitted to the anchylosed sacral vertebræ; the three elements of ilium, ischium, and pubes are only distinguishable in the young bird; the pubes do not meet in front, except in the ostrich, hence there is no symphysis or pubic arch. The femur is a strong

but shortish bone; it is pneumatic only in r ning birds, as *e.g.* the ostrich. The tibia is principal bone of the hinder extremities; it is l and strong. The tarsus and metatarsus are solde together to form one bone—the *tarso-metatar* Anteriorly this bone supports the toes; posterio the hallux. The toes never exceed four in num and the number of phalanges in each toe is const thus there are, counting from the hallux, two for first, three for the second, four for the third, and for the fourth.

The muscles of birds are pre-eminently red irritable; they are chiefly massed on the inner of the thighs, beneath the sternum and beneath pelvis; they act as ballast, and assist in maintai the equilibrium of the bird.

Physiological Processes of Aves.

Prehension of food, Deglutition, and Digestio The beak is the bird's only prehensile or except in the raptorial and scansorial families (w the foot is also used), and is variously modifie shape according to the habits and food of the b 'Thus it is short and strong in the grain-feed long and slender in the insectivorous warblers fly-catchers; notched in other insectivorous bi as in shrikes; short and gaping in the swallows night-jars, which catch their prey upon the w strong and hooked in the rapacious eagles and tures, which tear up their food; long, conical, of great strength in the digging rooks and in woodpeckers, which pierce the bark of trees; sh curved, and of great depth in the parrot tribe, w *can crush* hard nuts; exceedingly delicate and ta *ing in the* humming-birds, to enable them to p

trate the tubular corollas of flowers; ponderous and ungainly in the hornbills, toucan, and adjutants; long, strong, and pointed for the catching of fish, in the storks and herons; elongated and suctorial in the snipes and sandpipers, which seek their food in bogs or sand; flattened, grooved, and sensitive in ducks, geese, swans, and spoonbills; or it presents still other forms for holding fish, as in the pelicans, pilgrims, albatross, penguins, and auks.' — (*Marshall.*)

The salivary glands are comparatively small in all birds except the woodpeckers, in which they attain an enormous size.

The pharynx is simple. The œsophagus differs very widely in the different orders of birds. Before reaching the stomach the food is generally received into a temporary storehouse, called the crop; there is no crop in some aquatic birds, and it is variously fashioned in others where it does exist. Thus in the pelican the integuments beneath the lower mandible form a large pouch, which serves as a crop; in swifts and other insectivorous birds the back of the pharynx is dilated into a receiving-house for the insect food; but it is in the grain-feeders that the crop attains its largest size; in the common fowl it forms a lateral pouch on one side of the œsophagus, and in the pigeon it is composed of a bilateral sac similarly situated. The œsophagus is continued downwards from the crop to an expanded portion, called the '*proventriculus*,' or '*ventriculus succenturiatus*:' this is the true digestive stomach, and secretes the gastric juice. It is very variously shaped. The 'proventriculus' almost immediately leads into the muscular stomach or gizzard, which is also called the '*ventriculus bulbosus*.' In flesh-feeders the gizzard is comparatively thin, but in grain-feeders it is an enormously

powerful muscular sac. Stones or gravel are generally present to assist in the trituration of the hard, dry, food, and, as it were, to masticate it. The muscles composing the walls of the gizzard all radiate from two very strong anterior and posterior tendons. A pyloric valve, which is sometimes formed of several folds or ridges, conducts the food into a small intestine. This is short in carnivorous birds, long in the grain-feeders. There is no ileo-cæcal valve, but two cæca are very often present, and in some birds, as in the grouse, they attain a great size. The large intestine terminates in the dilated 'cloaca,' which receives the terminations of the urinary and generative organs.

The pancreas is large. The lymphatics and lacteals are fully developed. There are two equal-sized, symmetrical, thoracic ducts, which pour their contents respectively into the right and left subclavian veins.

Circulation.—The blood is somewhat hotter, as is the general temperature of the body, in birds than in Mammalia. The heart is perfectly four-chambered, and placed exactly in the median line; the aorta arches over the root of the right lung.

Respiration.—Every means are employed to render the respiration of birds rapid and complete. The lungs are large and perfectly cellular throughout; the bronchial tubes branch dichotomously throughout their remotest parts, and even pass right through them, by two large apertures, conducting the air into the general cavity of the abdomen, which is not yet separated from the thorax by a diaphragm (except in the apteryx and a few others). Fibrous septa divide the cavity into loculi. The air is even conveyed into the bones, which are extensively hollowed out for the purpose. In birds of flight it is the upper extremities alone which are pneumatic;

while in cursorial birds the air only reaches the lower extremities.

Expiration is effected by means of the sternum being forcibly drawn toward the vertebral column by muscular action; inspiration is effected by the resiliency of the sternum enabling it to return to its original position, and so expand the chest. The trachea of birds is interesting. Most birds have a double larynx, one situated at the top of the trachea in the position of the ordinary mammalian larynx, the other at the lower end of the trachea, where it is about to bifurcate into the two bronchi. When the latter exists it is the seat of vocalization. It is formed by modified rings and half-rings of the trachea. It is largest in the duck tribe.

Kidneys.—The kidneys are large, formed of cortical substance only, and lodged in recesses in the lumbar vertebræ; the ureters terminate in the common cloaca. There is no urinary bladder.

Nervous system.—The cerebral hemispheres (prosencephalon) are now much the largest elements of the encephalon, and partially conceal the olfactory lobes (rhinencephalon) in front, and the optic lobes (mesencephalon) behind. The medulla still supports a cerebellum, which consists of little more than a median lobe; small appendages are, however, present, in which are recognised the flocculi or pneumogastric lobules. There is no fornix, or corpus callosum. The optic lobes are not only inferior but lateral in position. This is peculiar to the class.

The cranial nerves have the same origin and distribution as in mammalia. The fifth sends twigs to the very end of the sensitive beak.

Senses.

Touch.—This sense resides chiefly in the bill *and tongue.* The soft corium of some birds' feet

is a tactile organ. The feathers are cutane growths, and formed upon a vascular papilla at t bottom of a deep pit; they are composed of ep dermic cells, variously shaped. Each feather consi of a quill or barrel, and a vane or beard, which again formed of barbs and barbules. The barbule from contiguous barbs, hook into each other like th latch of a door into its catch, so as to present a even and resisting surface to the opposition of th air.

Taste.—This is imperfectly developed. The tongue is covered with thick, horny papillæ. It is more perfect in the parrot tribe than in other birds.

Smell.—This sense is not very highly developed. Even in vultures, in whom it is more perfect than in most birds, it is now known that it is not by scent, but by sight, that they detect their prey. The turbinated bones, however, are present and somewhat convoluted. The nostrils are variously situated, generally upon the upper mandible; large and open in most birds, they are small in herons, and are absent in the pelicans. The posterior nares open into the pharynx frequently by a single instead of a double aperture: such is the case with the cormorants. The olfactory nerves leave the cranium by a single aperture, except in the apteryx.

Hearing.—An external, middle, and internal ear are now present for the first time. The external ear consists of a meatus only, there being as yet no pinna. The middle ear communicates by a large Eustachian tube with the pharynx, and by large mastoid cells with the cranium; these cells often pass from one side to the other. There is only one ossicle present, called the *columella*. The internal ear consists of vestibule, semicircular canals, and *cochlea*. The vestibule is well developed; the *canals are large*; the cochlea is a bent, but not ye

a spiral tube; it is, however, divided by a median *lamina spiralis* into a scala vestibuli and scala tympani.

Sight.—This sense is very perfectly developed. In addition to the ordinary tunics and humours, a singular vasculo-pigmentary structure is developed within the eye of birds, which passes from the entrance of the optic nerve towards the circumference of the lens. This is called the *marsupium* or *pecten*; its use is probably to absorb the too abundant rays of light. The nocturnal apteryx does not possess this structure. The lens is variously shaped; flat in the high-soaring birds of prey, it becomes much more spherical in the aquatic birds, and almost completely circular in the owl. The sclerotic is often strengthened by imbricated bony plates. Birds possess three eyelids; the lower eyelid is longer than the upper, and is freely moveable. The third or nictitating membrane is lodged in the inner canthus. It is swept across the eye by the action of two muscles placed at the back of the eyeball, called the pyramidalis and quadratus muscles; the former ends in a tendon, which passes through the other like a string through the top of a bag, and becomes attached to the lower corner of the membrana nictitans. There are two glands in connection with the eye; the lachrymal gland, situated in its ordinary position, beneath the external angular process of the frontal bone, and the Harderian gland, situated behind the conjunctiva at the nasal angle of the orbit. The iris of birds contains striped as well as unstriped muscular fibre.

Mammalia.

Definition.—Vertebrate animals possessed of mammary glands.

All but two possess teats. The thorax
fectly divided from the abdomen by a
tendinous diaphragm. There is no inferior
The heart is four-chambered, the aorta arches
the root of the left lung. The kidneys cons
both cortical and medullary substance. The ce
hemispheres are connected by a round commi
or 'lyra,' and a hippocampal commissure.
olfactory lobes give off many nerves, which
the cribriform plate of the ethmoid. The dif
parts of the encephalon are united by a pons V
The cerebellum possesses lateral lobes as well
median process.

The cranial vertebræ exhibit the greatest depa
from the character of vertebræ, and it is onl
analogy that we are still able to recognise i
mammalian skull the nasal, frontal, parietal,
occipital vertebræ. They articulate with the
by two condyles. The cervical vertebræ are al
seven in number, except in the Ai, or three-toed
in which there are nine; and in the Dugong, in
there are but six. The dorsal vertebræ su
pleurapophyses or ribs; the sternum is not k
except in the lowest order, the monotremes.
lumbar vertebræ are, as a rule, more numerous
in reptiles or birds. The sacral and caudal ver
vary much. The upper extremities show ma
differences between this class and Aves—the sc
is a flat expanded bone: the coracoid is, e
in Monotremata, merely a process of the sca
the clavicles are not always present. In a n
dactyle mammal, as *e.g.* a horse, in which the
present their simplest form, we recognise a hum
a radius, with which has coalesced the us
separate ulna; to which succeed a cluster of os
carpal bones; and these are succeeded by a

carpal bone and three terminal phalanges, which together form the digits. In mammals who possess more than one digit, this single digit corresponds to the middle finger. In the lower or pelvic extremity, the three elements of the pelvic arch—ilium, ischium, and pubes—are long distinctly recognisable. Taking still the horse as the type, we first find a strong femur, which articulates with an equally strong tibia, to which is joined the usually separate fibula; the ossicles which succeed form the *tarsal bones*, but the joint here formed is technically termed the knee; to these bones a single metatarsal bone succeeds, called the cannon bone; a triple row of phalanges, called respectively the greater pastern, lesser pastern, and coffin bone follow the cannon bone in a lineal series. Below the tarsal bones, the ossicles of both fore and hind limbs have received the same names. These digits correspond to the middle toe in those mammals which possess more than one digit.

Mammals are divided into three sub-classes, according to the character of their brains. 1. Lyencephala (λύω, *I loose*; ἐγκέφαλος, *brain*), loose-brained mammals; 2. Lissencephala (λισσός, *smooth*), smooth-brained mammals; 3. Gyrencephala (γυρόω, *I roll*), mammals with convoluted brains.

1. *Lyencephala* include two orders, Monotremata and Marsupialia. They do not possess a corpus callosum; the cerebral hemispheres are only connected by the round commissure and the hippocampal commissure. The females do not develop a placenta, and the young are prematurely born. They are, geologically, the oldest of all mammals.

2. *Lissencephala* include four orders—Rodentia, Insectivora, Cheiroptera (the bat family), and Bruta (the Edentata of Cuvier, including the ant-eaters

and armadillos). A corpus callosum connects cerebral hemispheres, which are, however, *still*] fectly smooth, and leave the olfactory lobes *in* fir and the cerebellum behind, more or less uncover

3. *Gyrencephala* are so numerous and importan that they are primarily broken up into three *series* 1. Mutilata, or maimed mammals, in whom the pelvic limbs are wanting, or apparently so. This series includes the whales, in two orders, Sirenia and Cetacea. 2. Ungulata, or hoofed mammals, including (*α*) Proboscidia, or animals with a trunk, such as the elephant; (*β*) Perissodactyla (*περισσός*, *odd*; *δάκτυλος*, *digit*), odd-toed mammals, such as the horse; and (*γ*) Artiodactyla (*ἄρτιος*, *even*; *δάκτυλος*), even-toed mammals, such as the cow. 3. Unguiculata, or clawed mammals: this series includes (*α*) Carnivora, (*β*) Quadrumana, and (*γ*) Bimana.

The characters of Gyrencephala are the possession of a convoluted brain, which overlaps the olfactory lobes in front and the cerebellum behind. The females are all provided during breeding with a placenta.

The several orders are distinguished by the following marks.

1. **Monotremata** possess a coracoid bone, which, like the same bone in birds, extends from the sternum to the scapula. The sternum is keeled. They are edentulous, or possess simple calcified teeth. A common cloaca receives the openings of the digestive canal and the urino-generative organs. There is a supplementary tarsal bone, or spur, in the male, which is perforated. Only two genera are found in this order, and both are Australian—the duck mole, and the spiny ant-eater, or echidna.

2. **Marsupialia** are mammals possessing pouch-*like bags depending* from the so-called marsupial

bones, which are processes of the pubic bones. In the male, this pouch is everted, and supports the penis; in the female, it is inverted, and serves as a receptacle for the offspring.

3. **Rodentia** are distinguished from all other Mammalia by their peculiar dentition. There are two long curved incisors in each jaw, which serve for gnawing the barks of trees or other substances, on which the rodent feeds. Their anterior surface only is covered with enamel; the rest of the tooth is composed of softer dentine, which, wearing down sooner than the enamel, always leaves a sharp chisel-like edge to the tooth. They are always growing from a persistent vascular papilla situated at their base. The incisors are separated from the molars by a wide interval. The beaver and the rat are examples of this order.

4. **Insectivora** are also distinguished by their dentition. In them we find incisors, canines, and molars. The latter are the peculiar teeth, their summits being furnished with numerous cusps. 'They are unguiculate, plantigrade, and pentadactyle, and they have complete clavicles.' This is a very widely distributed order of small smooth-brained mammals. The shrew, the hedgehog, and the mole are examples of the order.

5. **Cheiroptera** (χείρ, *a hand*; πτέρον, *a wing*) are distinguished by the peculiar modification which their digits undergo; they are all, except the thumb, immensely lengthened and provided with a membranous covering, which passes in a wing-like manner from the webbed phalanges to the lower extremities; the phalanges of the thumb are much shorter than the rest, and terminate in a hooked process, by means of which the animal clings to the *branches* of ivy or the projecting parts of walls.

Unlike the former orders of Lissencephala, the penis is pendulous, and the mammæ are pectoral. The bat and the roussette are examples of the order.

6. **Bruta** are many of them perfectly edentulous; others possess teeth, which, however, consist of dentine only, and are never replaced by a second set. They possess more ribs (twenty-three pairs) than other mammals. One species, the three-toed sloth, has nine cervical vertebræ.

They are all provided with long strong claws, which serve them for weapons wherewith to dig up their insect food. The testes are abdominal. There is a common cloacal outlet. The ant-eater, the armadillo, and the sloth are examples of this order.

7. **Cetacea** (*κῆτος, a whale*) are fish-like in form and habits. They are either edentulous or monophydont, *i. e.* possess but one set of teeth. They are the largest of all living forms, and, next to the elephant, their brains are the heaviest known, weighing about five pounds. The nostrils are situated on the top of the head, and constitute the *blow-holes* or *spiracles*. The peculiarities of their respiration will be described under the Physiology of Mammalia. This order includes all the whales.

8. **Sirenia** (*σειρήν, a mermaid*) are phytophagous in their diet, and consequently possess molars as well as incisors, they develop both a temporary and a permanent set of teeth; *i.e.* they are diphyodonts. The nostrils are situated on the top of the snout, and are beset with stiff bristles. They possess vesiculæ seminales, which the former order of Mutilata do not.

The dugong and the sea-cow are illustrations of this order.

In one genus (Manatus) there are but six cervical vertebræ. In all, the mammæ are pectoral, *whereas in the* Cetacea they are inguinal.

Neither Sirenia nor Cetacea possess clavicles.

9. **Proboscidia** are characterised by a peculiar dentition, and by a singular modification of the nose. There are no canine teeth, but the incisors are developed into *tusks*, which, in the elephant, grow from the upper jaw; in the dinothere they grow from the under jaw; and in the mastodon from both jaws. These incisors are associated with molars, of which there are not fewer than six on each side of both jaws. The nose is prolonged into a long, flexible, highly-sensitive, muscular *trunk*, which is terminated by a small prehensile appendage like a finger. They are pentadactyle. The testes are abdominal; the mammæ are pectoral.

10. **Perissodactyla** comprise the odd-toed Ungulata, whether the digits be one, as in the horse, or three, as in the rhinoceros. The dorso-lumbar vertebræ are numerous, but are never fewer than twenty-two. The femur possesses a third trochanter. If the specimen be horned, the horn is either single, or one horn is placed behind another, but always in the median line. The alimentary canal is simple, but the cæcum is very large. Most of the Perissodactyla are fossil, *e.g.* Palæotherium, Hipparion, &c. It is now represented by the horse, the rhinoceros, the tapir, and the little hyrax.

11. **Artiodactyla** comprise the even-toed Ungulata. 'The digit answering to the third in the pentadactyle foot is unsymmetrical, and forms, with the fourth, a symmetrical pair.' The number of dorsal and lumbar vertebræ may each vary in different species, but added together, they invariably number nineteen. The Artiodactyles are not always horned, but if they possess these appendages, they are always double, and are supported by a bony core; they are never placed in the median line.

Most Artiodactyla possess a complex stomach, and a comparatively small cæcum. Many species are extinct, *e.g.* Microtherium, Anoplotherium, &c., but it is also very numerously represented at the present day. Ruminants, hippopotami, and peccari are examples of this large and important order.

12. **Carnivora,** the first order of the Unguiculata (unguis, *a nail*) or nailed mammals, comprise the principal banditti of nature in the fierce beasts of prey. They are distinguished by the possession of retractile or non-retractile claws, and their dentition. There are both milk and permanent teeth, for which the formula is as follows:—incisors, $\frac{3-3}{3-3}$; canines, $\frac{1-1}{1-1}$; molars, $\frac{3-3}{3-3}$. The canine teeth are always very largely developed, and serve as powerful lethal weapons. The clavicles are rudimentary, or quite absent. They are subdivided, according to the character of their limbs, into *Pinnigrades* (pinna, *a feather*; gradior, *to walk*), which includes the seal and walrus tribe; *Plantigrades* (planta, *the sole of the foot*), which includes the bears, and all flat-footed carnivora; and, lastly, the *Digitigrades*, or carnivora that walk on their toes, which subdivision includes the cat and dog tribe.

13. **Quadrumana** are distinguished from all other mammals by the peculiar modification of their limbs, which are terminated by hands. This invariably applies to the hinder limbs, not invariably to the fore limbs. In every quadrumanous animal, or monkey, the hind limb is terminated by a hand; in every man, by a foot. The essential feature of a hand is the possession of an opposable digit, or thumb. The dental formula is the same as that of man, or else there are three premolars in each jaw instead of two. The summits of the teeth are never in the same level. Quadrumana are subdivided,

according to the position of their nostrils, into—1. Strepsirrhines, or monkeys with twisted nostrils, such as the lemurs and aye-ayes; 2. Platyrrhines, or monkeys with simple sub-terminal nostrils, such as the spider monkeys; and 3. Catarrhines, or monkeys with oblique nostrils approximating below, separating above, such as the gorilla and the chimpanzee. All Quadrumana are clothed with hair.

14. **Bimana** — contains but one genus and one species, Homo. The distinguishing characteristics of this order are these: The summits of the teeth form a nearly perfect level, and are not separated from each other by an interval; the dental formula is as follows: i. $\frac{2-2}{2-2}$; c. $\frac{1-1}{1-1}$; p.m. $\frac{2-2}{2-2}$; m. $\frac{3-3}{3-3}$. The great toe is not opposable to the other digits. The arms are shorter than the legs; the reverse of this is the case in the Quadrumana. 'The human foot is broad, flat, plantigrade, with the sole not inverted as in the Quadrumana, but applied flat to the ground.' 'The whole vertebral column, with its slight alternate curves, and the well-poised, short, but capacious subglobular skull, are in like harmony with the requirements of the erect position.' *

Physiological Processes of Mammalia.

Prehension, Deglutition, and Digestion.—All Mammalia use their lips as organs of prehension, and are assisted, in Bimana, Quadrumana, Rodentia, Marsupialia, by their fore limbs. The Carnivora tear their prey with their claws, but do not use them as prehensile organs. The proboscis of the elephant, the snout of the tapir, the long muscular and viscid-tipped tongue of the ant-eater, and the long tongue of the giraffe, are special prehensile organs.

* Owen, *Comp. Anat. of Vertebrates*, vol. ii. page 293.

The teeth of Mammalia differ widely in the different orders, both in their number, shape, and size. The echidna, and the myrmecophaga, or true ant-eater, have no teeth. The narwhal has but *two*, one of which is always rudimentary. The dolphin has 190. The elephant generally has six, which are succeeded by a second set, which do not grow from below, as in man, but from behind, and as they advance they push out the previous tooth; by this contrivance the few toothed elephant is never left without sufficient grinders. The typical number of teeth in the Rodentia is 20, in Quadrumana 44, in Bimana 32. The teeth of the Cetacea are very peculiar; the cachelot whale and dolphin tribe have a large number of conical teeth, composed of dentine, lodged in wide sockets; the Balæna mysticetus (whalebone whale) presents, instead of true teeth, a series of plates of whalebone which are ranged in rows along the upper jaw—from these plates depend a long fringe of finely-divided whalebone threads which act as a sieve. The huge animal swims through the Polar seas with his mouth wide open, and receives into his gigantic maw thousands of little mollusca, which abound in those regions, the Clio borealis being the most abundant of all; they are entangled in the meshes of whalebone, and swallowed one by one down the narrow œsophagus. This constitutes the chief food of this leviathan of the deep.

The salivary glands are developed much as in man throughout the Mammalian class, except in the Cetacea, where neither salivary nor lachrymal glands exist, and in the ant-eater, in which animal they are enormously developed, and pour their secretion into a special cervical reservoir, called a *salivary bladder*.

There are three distinct types of stomach met with *amongst Mammalia*—the simple, the compound, and

the complex stomach. The *simple* stomach consists of a single cavity, presenting a cardiac recess or pouch at the œsophageal end, and narrowing to a pyloric valve at the duodenal end; throughout it is lined by an epithelium which secretes gastric juice; this form of stomach is met with in Bimana, Quadrumana, Carnivora, and in some Cheiroptera, Insectivora, Bruta, Cetacea, Marsupialia, and Monotremata.

The *compound* stomach consists of a variety of the former; the single cavity being partially divided by folds into two or more spaces; the histological elements of the mucous membrane are however the same throughout. This form of stomach is met with in some Cheiroptera, in the manis or pangolin, amongst Bruta, in the kangaroo, in the carnivorous Cetacea, in some Rodents, and still more typically in the sloths. The ant-eater possesses a sort of crop, to which succeeds a stomach with such thick muscular walls as to recall the gizzard of a bird; a resemblance that is still further borne out by the ant-eater's stomach frequently containing gravel, which, like the stones met with in a bird's gizzard, serve the purpose of teeth.

The *complex* stomach is peculiar to ruminants, nd is the most interesting of all. In these animals he stomach is divided into four distinct cavities: , the paunch, or rumen, or ingluvies, or panse; 2, e reticulum, or honeycomb, or bonnet; 3, the asum, manyplies, psalterium, or feuillet; and 4, abomasum, reed, or rennet.

The *paunch* is by far the largest of all the cavities he adult animal, to whom it serves as storage for herbage; in the young ruminants the fourth ach is, on the contrary, larger than the paunch. *paunch* is lined with a dense white squamous elium. Its office is to store the food, and mix

it with the water which it contains; its secretion has scarcely any digestive function. In the camel, llamas, and dromedaries, the paunch contains a number of pits, whose mouths are closed by muscular rims, and which serve as water-butts for storing up fluid when the animal is going a long, arid journey. There are several of these butts in the stomach of the camel; they measure about eighteen inches in length, by six inches in breadth, and three inches in depth. They are subdivided by muscular partitions into many distinct cavities.

The *reticulum* is very much smaller, and presents an appearance like a honeycomb, whence its name. The polygonal spaces into which it is divided serve to fashion the food into small round pellets, which are one by one regurgitated into the animal's mouth, there to undergo a second mastication; this constitutes rumination. A certain amount of the fluid parts of the food are absorbed by the veins of the reticulum. The mucous membrane is papillated. A groove leads along the upper border of the reticulum direct from the œsophagus to the third stomach, the manyplies; this can be converted into a complete canal, by the muscular action of the walls of the reticulum, and so the food must then pass direct from the œsophagus into the manyplies.

The *manyplies* is of an elongated form, and has its mucous membrane arranged in parallel longitudinal folds, like the leaves of a book—whence its French name 'le feuillet'—small folds alternate with larger ones. There are some forty in the sheep, and about eighty in the ox. The mucous membrane is villous. Further digestion of the soluble saccharine and fluid portions of the food goes on here, before it is passed on into the rennet, or fourth stomach. The *rennet is the true digestive* stomach, and homologue of the

single stomach of man. It is the largest cavity of all except the paunch. The mucous membrane is highly vascular, and is thrown into longitudinal rugæ.

The *rennet* contains the stomach tubes which secrete the gastric juice. It is here that the albuminous principles of the food are extracted and absorbed by the veins.

In all Mammalia a pyloric valve is present; and all except Cetacea and a few Bruta and Cheiroptera possess a distinction between large and small intestines; these latter exceptions do not exhibit any such distinction, nor do they possess an ileo-cæcal valve. The digestive canal is almost invariably longer in the herbivorous than in the carnivorous mammals, *e.g.* the canal is as 30 to 1 of the entire length of the animal in the sheep, and as 5 to 1 in the cat and dog. A cæcum generally exists, and is developed in relation to the kind of diet; in flesh-feeding Mammalia it is comparatively small, or even absent, while it is very large in the vegetable-feeders. In the horse it is three times as large as the stomach.

Man, apes, gibbons, and the little wombat, are the only mammals possessed of a vermiform appendix.

Circulation.—In all mammals the heart consists of four distinct chambers: two auricles, and two ventricles which form a right and left side. The right side is the venous, the left the arterial. The right auricle receives the impure blood from the entire body, transmits it to the right ventricle, which pours it into the lungs, whence it is returned by the pulmonary veins to the left auricle, which transmits it to the left ventricle; the aorta leading from this cavity carries the blood over the whole body; the left side of the heart is thus engaged with the *systemic* circulation, the right with the pulmonic circu-

lation. In man and the higher apes the h[illegible] inclines to the left side, in the rest of Mammalia it is in the median line. In the lower Mammalia the branches from the arch of the aorta are symmetrical; in all the higher mammals they are unsymmetrical. The brachial artery in the cat tribe passes through a foramen in the humerus above the inner condyle, to protect it from pressure; a similar arrangement is met with in the artery of the coffin-bone in the horse. When a large artery breaks up into a number of branches, all of considerable calibre, which freely inosculate with each other, a 'rete mirabile' is formed; such an arrangement must manifestly delay the rapidity of the current of blood and equalise the pressure in the passage of blood through a part; it is met with in the axillary arteries of sloths, the internal carotid arteries of ruminants, and the aortic and thoracic intercostals in Cetacea. In regard to the venous system; man and all higher, and many of the lower Mammalia only possess one superior vena cava; in Rodentia and Pachydermata there are two. In the Cetacea, venous as well as arterial plexuses exist, and serve as reservoirs for the impure blood during the protracted immersion of the animal.

In all mammals except the camel, in which they are oval, the blood discs are circular.

Respiration.—All Mammalia possess a diaphragm. In all except the horse, elephant, and most Cetacea, the lungs are divided into lobes, not exceeding three on the left, and five on the right side. In the exceptions named the lungs are not lobed. The only peculiar respiration is that of the Cetacea. The nostrils or *spiracles* in these fish-like mammals are placed on the top of the head, and lead directly down to the

pharynx, the top of which is surrounded by a strong sphincter muscle, which keeps it closed except when the whale 'blows.' The soft palate is prolonged to a considerable extent, so as to form a strong musculo-cartilaginous plug, which perfectly blocks up the passage from the mouth into the pharynx and larynx; by this means the animal can swim about with its head under water, and its mouth wide open, and yet never be in danger of any water getting into the air passages. After the air that the animal has breathed has become too impure for further use, the whale rises to the surface, and closing its mouth, it forces the water against the plug of the soft palate and drives it out, pumping the water into large cavities which surround the sides of the spiracle; the top of the pharynx contracts, the muscular summit of the spiracle relaxes, the muscular walls themselves contract and force the water violently from the spiracle into the air; in other words, she 'blows.' When all the water is expelled, a fresh supply of air is taken in, and when a sufficient quantity is received, the leviathan dives down again 'full fathoms five.'

Kidneys.—The kidneys always consists of a cortical and medullary portion. In all Mammalia the kidneys are at first lobulated, and this condition persists in many of the class, particularly in the bears, otters, seals, and some Cetacea, and to a less extent in the ox.

Nervous System.—The *prosencephalon* (or cerebral hemispheres) now forms by far the largest portion of the brain, more or less overlapping the *rhinencephalon* in front, and the *mesencephalon* behind. The mesencephalon (or optic lobes) is no longer *bigeminal*, but constitutes the *quadrigeminal* bodies. A pons Varolii unites the various parts of the brain. The cerebel-

lum consists of lateral hemispheres as well as a median verniform process. These characters appl[illegible] to all Mammalia. Monotremata, Marsupialia, Rodentia, Insectivora, Cheiroptera, and Bruta possess perfectly smooth unconvoluted brains; the two first-named orders do not possess a corpus callosum, all the others do.

The remaining Mammalian orders all possess brains more or less convoluted; and this increase of surface, and consequently of grey matter, we invariably find associated with an increase of intelligence. The main difference between the brains of Bimana and Quadrumana lies in the greater complexity of man's brain, the greater depth of the sulci, and greater amount of grey matter; both are however developed on one common plan, and both possess a hippocampus major, and posterior cornu, in the lateral ventricles, which formerly were supposed to be confined to the human brain.

Senses.

Touch.—Tactile corpuscles, which are the special seats of the sense of touch, abound in the lips of nearly all Mammalia; they are also abundant in the hands of Bimana, which are the most perfect of all tactile instruments; in the hands and feet of Quadrumana; in the snouts of the tapir, the pig, and the rhinoceros, in the tip of the elephant's trunk; in the general integument of Cetacea, in the base of the whiskers or *vibrissæ* in the cat tribe, and at the tip of the prehensile tail of some monkeys. The wings of bats are also abundantly supplied with nerves and tactile corpuscles, and constitute a very perfect instrument of touch.

Taste.—The tongue is the seat of the sense of

taste in all Mammalia except the Cetacea, who are probably devoid of this sense altogether. Bears possess two or three small accessory tongues. The glossopharyngeal nerve, which is distributed chiefly to the circumvallate papillæ at the back of the tongue, is the special nerve of taste. Secondary papillæ are present on all the papillæ of the tongue; and in Carnivora these secondary papillæ become much lengthened and recurved, and serve to rasp the flesh from off the bones. The long tongue of the ant-eater, which can be protruded for sixteen or eighteen inches, is composed of circular muscular fibres, which elongate it, and of longitudinal muscular fibres, which shorten it. Substances must be soluble to be sapid.

Smell.—This sense is present in all Mammalia except Cetacea. Mammalia possess not only anterior and posterior nares, but a nose, made up of cartilages, ligaments, and muscles. This is enormously developed in the elephant, forming the trunk. The cribriform plate of the ethmoid bone is perforated by several apertures instead of by one or two, as in the other vertebrate classes. The turbinated bones are three in number, and are all much convoluted, so as to increase the sentient surface; and many of the neighbouring bones often contain hollow spaces or sinuses. In those animals, such as the dog, who possess the faculty of scent, we find the turbinal bones rolled upon themselves to a very considerable extent, forming the 'labyrinth.' In many Cetacea the olfactory lobes and nerves are exceedingly small, and in the dolphins and porpoises they are absolutely wanting.

Hearing.—All Mammalia except Cetacea, seals, moles, duck-moles, and armadillos, possess a pinna, as well as an external meatus. In those animals, such as the bats, in whom the sense is very acute,

the pinna is very extensive. The tympanic cavity is always traversed by three ossicles, a malleus, incus, and stapes, which are variously shaped. In the elephant the tympanum is separable from the rest of the organ of hearing, and constitutes a large shell-like bone, called the 'ear bone.' A cochlea, forming from one-and-a-half to five turns, is always present, as are also a vestibule and three semicircular canals.

Sight.—The tunics and humours are the same as in man. Nocturnal mammals have comparatively large eyes. The mole possesses extremely small eyes, and is said not to possess any optic nerve. In Cetacea, as in fishes, the sclerotic is immensely thickened, and enables the eyeballs to sustain the great pressure to which they are subject during their profound dives.

All mammals except Cetacea possess lachrymal glands and eyelids; the true Cetacea possess only a *membrana nictitans.* Ruminants possess a large gland, called the *Harderian gland,* which assists the lachrymal gland in moistening the eyeball; it is situated at the inner canthus of the eye.

The muscles of the eye are the same, and supplied in the same way, as those in man; but in addition to the four recti and two oblique muscles, there is usually a funnel-shaped muscle, called the *choanoid* muscle, interposed between the recti and the optic nerve. The contraction of this muscle serves to protrude the eyeball.

Nearly all Mammalia, except Bimana, Quadrumana, Bruta, and Monotremata possess a glistening structure situated at the bottom of the eyeball, called the *tapetum lucidum.* It serves the purpose of a concave reflector, and illumines the eyes of the animals which possess it in the dark.

CHAPTER IX.

GENERATIVE ORGANS, AND MODE OF REPRODUCTION AMONGST THE OVIPAROUS VERTEBRATA.

Fishes.—The ovary, called the *roe*, and the testicle, called the *milt*, both situated against the vertebral column, occupy a large extent of the thoracico-abdominal cavity. In the osseous fishes, the countless myriads of ova, forming not merely the germs of future races, but serving as food for many of the present, are extruded from the ovary by a canal, situated immediately behind the anus, and in front of the urinary canal. These ova are impregnated external to the body of the female by the semen of the male, which is emitted loosely into the water; coming in contact with them, it vivifies them.

In the cartilaginous fishes, the ova either pass from the ovary into the general cavity of the abdomen, whence they escape by two apertures, as in the eel, or rupturing the ovarian capsule they pass into distinct oviducts. In the highest of the Chondropteri, *e.g.* the shark, impregnation takes place internally; the male firmly holding the female during coitus by means of two boot-like processes, called 'claspers.'

Amphibia.—The ovaries and testes are situated, as they are in the whole of the oviparous tribes, in the lumbar region. Their contents are poured into a cloacal opening, common to themselves and the urinary and digestive organs. The male frog holds his spouse in a close embrace during the whole period

of oviposition, and impregnates the ova during the period of their extrusion from the body of the female.

Reptiles.—The female possesses two oviducts, which terminate in a common cloaca. The male is provided with an intromittent organ. In Ophidia the penis consists of two separate bodies (corpora cavernosa), deeply grooved along their upper surface, along which groove the semen trickles. In Chelonia the corpora cavernosa, separate at first, unite to form an organ of considerable size. Impregnation takes place internally.

Birds.—The ovaries of the female are held to the vertebral column by folds of peritoneum. The *right* ovary and oviduct is always atrophied, so that it is the *left* alone which produces ova. The oviduct, which succeeds to the ovary, opens into a common cloaca; it is nearly straight, except during sexual excitement, when it presents three principal curves; the upper expanded part, which first receives the ovum, is called the *infundibulum*, the narrow contracted portion below constitutes the *isthmus*, and the wide and straighter portion near the termination is badly called the *uterus*. The epithelium lining the oviduct differs in each of these situations, and in each the ovum obtains a fresh covering; first, the *white of the egg*, next, the *membrana putaminis*, and lastly, in the uterus, the *calcareous shell*.

The testes of the male are situated in the lumbar region, and increase very remarkably in size during the breeding season. Male birds that pass an aërial or arboreal existence only possess two sensitive papillæ, which are merely capable of juxtaposition; but aquatic birds and the ostrich possess very perfect intromittent organs, in which both corpora cavernosa *and a corpus* spongiosum are easily distinguishable.

The ovum is composed of the following parts,

which are essentially similar to the structure of the mammalian ovum. The entire ovum is contained in a delicate transparent membrane, the *vitelline membrane*, corresponding to the mammalian zona pellucida, parent of the future chorion; within this membrane the *yelk* is situated, composed of a yellow oleaginous material with a number of granules. Upon the surface of the yelk we find another little membranous sac, called the *cicatricula* or *blastoderm*; this is opaque, and contains within its interior the germ of the future animal. This germ presents the appearance of a minute transparent vesicle, and is called the *vesicle of Purkinje*, or the *germinal vesicle*. The egg of the bird and the egg of the lower Vertebrata are like each other in all essential respects; in shape, the reptilian egg is always equal at both ends; the avian egg is larger at one end than the other. The most important differences are these: the egg of the bird contains a *chalaza* and *air-chamber*, while the egg of the lower vertebrates do not; and for the purposes of incubation the bird's egg also contains more albumen, and the shell is much more complex. Impregnation takes place by the spermatozoa of the male being conveyed along the oviducts (or if there are none, directly) to the *cicatricula*.

The coverings which the ovum of the bird obtains in its passage along the oviduct are the following: *albumen*, *chalaza*, *membrana putaminis*, and *calcareous shell*.

The *albumen* is the 'white of the egg;' it is secreted by the lining membrane of the oviduct, directly after the ripe ovum has escaped from the ovisac. The ovisac is called in such a case the *calyx*; the albumen surrounds the *membrana vitelli*.

The *chalaza* is formed by some of this albumen becoming inspissated, and twisted into two small

cords at either end of the yelk, durir
lutions.

The *membrana putaminis* is secreted
duct, just before reaching the *uterus*;
opaque tough membrane lining the shell
it is separated into two layers, within whi
some highly oxygenated air, for the chic
just before breaking its shell; this litt
called the *air-chamber*.

The *shell* is secreted by the epitheli
uterus; minute interspaces being left
calcareous particles for the purpose of tra

CHAPTER X.

GENERATIVE ORGANS AND MODE OF REPRODUCTION AMONGST MAMMALIA.

Mammals are all born alive, but the offspring of the two lowest orders, Monotremata and Marsupialia, are so prematurely born as to be termed ovoviviparous, the offsprings of all other mammals being viviparous. The male generative organs of mammals present many peculiarities, but all are formed of two dense corpora cavernosa, which are always fixed to the pelvic bones, with a superadded corpus spongiosum; additional glands to the testes are generally present, none of which are found in the other vertebrate classes; these are the prostate gland, the vesiculæ seminales, and Cowper's glands; all of them prepare a secretion which is poured into the urethra, sometimes by separate ducts, sometimes converging to empty themselves into the excretory duct of the testes, called the vas deferens, where they mingle their secretion with the semen.

The testes are lodged in the abdomen in the elephant, the Cetacea, and the seal; they pass out of the abdomen through the inguinal canals and rings in most of the other Mammalia, and are lodged in a scrotal bag.

The female organs of generation present even greater varieties than the male. In the Monotremata and Marsupialia the ovaries are large, and like the ovaries of a bird, racemose or grape-like in their appearance; the contained ova are correspondingly large, and furnished with a considerable quantity of

yelk, which serves as nourishment for the embryo prior to its extrusion from the body of the female. The oviducts, which succeed to the ovaries, present dilatations in part of their course, which dilatations are termed *uteri*; and these open into a cloacal chamber: not only is there a double uterus in most orders, but the vagina likewise is completely separated into two channels. Prior to birth the embryo derives its nourishment from the surrounding yelk; the prematurely born offspring is at once transferred by the mother to one of the nipples of the mammary glands, to which it adheres, and where its further development takes place.

In all Mammalia the passages from the ovaries to the uteri are no longer called oviducts, but 'Fallopian tubes.' The ovisac is termed the 'Graafian vesicle;' this is much denser than the delicate ovisac of the oviparous vertebrates, and leaves a permanent scar whenever an ovum escapes; this scar constitutes what is known as a 'corpus luteum.'

The young of all mammals except those of Monotremata and Marsupialia is retained within the uterus until a much later period of development, and as the yelk surrounding the blastoderm becomes more and more scanty, some fresh means of support is required for the embryo. A vascular connection is therefore established between the mother and the fœtus, by means of which the latter is supported during this period of gestation; this vascular connection becomes developed into a body called the 'placenta.' The Rodentia possess a double uterus, like the Marsupials, but the ovaries are no longer racemose, and the Fallopian tubes are very small, showing that the *ovum which they conduct to the uterus must likewise be exceedingly* minute. In other mammals the *double uteri unite* to form a central portion,

is called the *body* of the uterus, and this constitutes the entirety of the organ in the higher mammals. In those mammals which give birth to more than one offspring at a time, we find the sides or *cornua* of the uterus numerous and largely developed; this is especially the case in the sow. As soon as the ovum is passed from the ovaries along the Fallopian tubes into the uterus, the latter cavity in most Mammalia secretes a thick membrane, which is termed the *decidua*, because it is shed on the expulsion of the fœtus from the uterus.

The shape of the placenta differs widely in the different mammalian orders, and forms an important means of classification; thus it is *zonary* in Carnivora, Proboscidia, and Hyracoidea; it is *discoidal* in woman, the Quadrumana, Insectivora, Cheiroptera, and Rodentia; whilst in Ungulata and Cetacea there is no decidua, hence the placenta is said to be *non-deciduate*.

CHAPTER XI.

DEVELOPMENT OF VERTEBRATES.

Up to a certain period the young of all vertebra
are developed in the same manner. The followi
description is taken from Rymer Jones, and is as br
as it is possible to make it. 'No sooner has incul
tion commenced than the blastoderm becomes c
tinctly separate from the yelk and the membra
vitelli, and as it begins to spread assumes the fo
of a central pellucid spot, surrounded by a brc
dark ring; it at the same time becomes thicker
and prominent, and is soon separable into th
layers; of these the exterior is a serous layer; t
internal, or that next the yelk, a mucous layer; a
between the two is situated a vascular layer, in wh
vessels soon become apparent. These three lay
are of the utmost importance, as from the first m
tioned all the serous structures, from the second
the mucous structures, and from the third the ent
vascular system of the embryo originate.

'Towards the close of the first day of incubat
the blastoderm has already begun to change its appe
ance, and two white filaments are apparent in
middle of the central pellucid circle. Supposin
longitudinal section of it at this period, the membra
vitelli will be found to have become more promin
where it passes over the germinal space. At
commencement of the second day the anterior port
of the embryo is dilated, and bent down, so as
inflect the three membranes of the blastoderm at t

point. At the conclusion of the second day this inflection is carried still further, and from the vascular layer a single pulsating cavity, the *punctum saliens* (the first appearance of a heart) has become developed. The serous membrane has at the third day become reflected to a considerable distance over the back of the fœtus; at one extremity investing the head with a serous covering, while at the opposite it in like manner covers the tail; it is this reflection of the serous layer which forms the *amnion*. The mucous layer is now seen to line the as yet open space which is to form the abdominal cavity, and by its inflections gives birth to the rudiments of the abdominal viscera. From the vascular layer has been developed the heart. The allantois likewise begins to make its appearance. . . About the one hundred and twentieth hour from the commencement of incubation, the vascular layer of the blastoderm has spread extensively over the yelk; and as the vessels formed by it become perfected, they are found to converge to the navel of the embryo, and to constitute a distinct set of arteries and veins (omphalo-mesenteric), communicating with the aorta and with the heart of the fœtus, and forming a vascular circle surrounding the yelk.

'As soon as the intestinal system of the embryo is distinctly formed, the membrane enclosing the yelk (vitellicle) is seen to communicate with the intestine by a wide duct (ductus vitello-intestinalis), whereby the nutritive substance of the yelk enters the alimentary canal to serve as food. Gradually, as growth advances, the yelk diminishes in size, and at length, before the young bird is hatched, the remains of it are entirely withdrawn into the abdominal cavity, where its absorption is completed.

'While the above phenomena are in progress, the

sides of the abdominal cavity, which are still o
anteriorly, are occupied by transitory secret
organs, named *corpora Wolffiana*.

'These organs act as temporary kidneys, and p
their secretion into a membranous sac called
allantois. This serves not only as a receptacle
this secretion, but also as a respiratory organ, an
richly supplied with blood. 'The arteries are
rived from the common iliac trunks of the emb
and of course represent the umbilical arteries of
human fœtus; the vein enters the umbilicus, a
passing through the fissure of the liver, pours
blood, which it returns from the allantois in
arterialised condition, into the inferior cava, as
the umbilical vein of Mammalia.'

Such are the briefest outlines of the developm
of the oviparous Vertebrata: let us turn to
viviparous Vertebrata. 'There is not the least do
that the materials for the earliest growth of
mammalian embryo are absorbed in the cavity
the womb, and that its formation from a *blastod*
is exactly comparable to what occurs in the egg
bird. But precisely at that point of developm
when the marsupial embryo is expelled from
uterus of its parent, namely, when the funct
both of the vitellicle and of the allantoid appar
become no longer efficient either for nutritio
respiration, a third system of organs is develope
the placental mammifer, whereby a vascular in
communication is established between the fœtus
the uterine vessels of the mother, forming what
been named by human embryologists the *place*
The vessels which passed merely to the allantoi
the bird, now pass from the allantois to the sha
chorion, where the placenta is becoming develo
and, as this organ grows, the allantoid sac atro

and disappears. The vitellicle, with its pedicle, are likewise of very small size. The arteries which are diverted from the allantois to the placenta constitute the umbilical arteries; the vein carrying arterial blood, and immensely enlarged, forms the umbilical vein.

Origin of the Notochord and the Vertebral Column.

The middle or vascular layer of the embryo develops not merely all the vascular system, but likewise the skeleton. 'The earliest indication of embryo form consists in the production of the "primitive trace" and groove, which takes place in the part of the upper and middle layers to be occupied by the embryo. The deepening of this groove by the elevation of its sides lays the foundation of the cerebro-spinal canal, and this is finally closed in superiorly by the meeting and union of the elevated and approximated margins of the groove. At the same time, there is enclosed within the cavity the medullary substance derived from the upper layer, which constitutes the rudiment of the brain and spinal marrow.

'It is below and around this tubular cerebro-spinal canal, and in the substance of the middle germinal layer immediately adjacent to it, that the cranio-vertebral part of the skeleton takes its origin. Immediately below the cerebro-spinal groove, previous to its closure, there appears in the substance of the middle layer a linear condensed structure, termed *chorda dorsalis*, or *notochord*. Round this, at a later period, the base of the skull and bodies of the vertebræ are developed.

'Soon after the extension of the two upper germinal

layers in the dorsal direction has given rise to *the* neural cavity and its contained cerebro-spinal *axis*, the incurvation of all the three layers in a downward direction results in the formation of the walls of the visceral cavities of the body, and thus, from the *chorda dorsalis* as a centre, there proceeds, upwards, a neural, and downwards, a hæmal arch.

'In the middle layer itself, which is destined for the production of the most complicated parts, the thickened portion which is next to the *chorda dorsalis* on either side is separated from the part which is more remote; and it is in the inner portion now mentioned that there are produced, at a very early period, those structures which have been called *primitive*, or *primordial vertebræ*, by embryologists, the formation of which constitutes the next stage in the progress of the earliest development of the skeleton. These rudimental structures consist of small, dark, quadrilateral patches of condensed germinal substance, to the number of three or four, situated on each side of the chorda dorsalis. The anterior corresponds to the atlas vertebra; and, in the subsequent increase of their number, the new ones make their appearance farther and farther backwards, or towards the caudal extremity.

'The so-called primordial vertebræ have, however, a more extended destination than to serve as the basis of formation of the elements of the vertebral column; for each pair contains the rudiments not only of the osseous and cartilaginous parts of a vertebra, which cross the middle plane, but also in the thoracic region the portion of a rib, and throughout *the whole* extent the central part of a pair of spinal *nerves, and the* cutaneous and muscular parts which *cover the whole* vertebral region.' *

* Quain and Sharpey, 7th edition.

CHAPTER XII.

Professor Huxley classifies Vertebrata as follows:—

He divides them, in the first place, into three classes: 1. Mammalia; 2. Sauropsida (*σαύρα, a lizard*; *ὄψις, look, aspect*), which includes both Aves and Reptilia; and 3. Ichthyopsida (*ἰχθύς, a fish, ὄψις*), which includes Amphibia and Pisces.

1. **Mammalia** he arranges, according to the placental characters of the female, into those possessing a discoidal deciduate placenta, those possessing a zonary deciduate placenta, those possessing a non-deciduate placenta, and those not possessing a placenta at all. Each of these sub-classes contains the following orders.

Mammalia possessing a discoidal deciduate placenta:—

1. Primates.
   - *α.* Anthropidæ (Bimana).
   - *β.* Simiadæ (Quadrumana).
   - *γ.* Lemuridæ (Quadrumana).
2. Insectivora.
3. Cheiroptera.
4. Rodentia.

Mammalia possessing a zonary deciduate placenta:—

1. Carnivora.
2. Proboscidea.
3. Hyracoidea (consisting of the single genus Hyrax).

Mammalia possessing a non-deciduate placen
1. Ungulata.
2. Cetacea.
3. Sirenia.
4. Edentata.

Mammalia not possessing a placenta at all.
1. Marsupialia.
2. Monotremata.

2. Sauropsidæ (*Aves et Reptilia*).

Aves into three orders.

1. Saururæ (*σαύρα, a lizard*; *οὐρά, a tail*): contains the fossil archeopteryx.

2. Ratitæ (ratis, *a raft*): include birds w sterna are not keeled, *e. g.* ostriches.

3. Carinatæ (carina, *a keel*): birds whose st are keeled.

Reptilia into four living and five extinct orde

1. Crocodilia,
2. Lacertilia,
3. Ophidia,
4. Chelonia,

} living.

1. Ichthyosauria (*ἰχθύς, a fish*; *σαύρα*),
2. Plesiosauria (*πλησίος, near*; *σαύρα*),
3. Dicynodontia (*δι-, two*; *κύων, a dog*; *ὀδούς, a tooth*),
4. Pterosauria (*πτέρον, a wing*; *σαύρα*),
5. Dinosauria (*δεινός, terrible*; *σαύρα*),

} ext

3. Ichthyopsida (*Amphibia et Pisces*).

Amphibia into four orders.

1. Urodela (*οὐρά, a tail*; *δῆλος, manifest*): teus, newts, &c., &c.

2. *Batrachia* (*βάτραχος, a frog*): frogs and t

3. *Gymnophiona* (γυμνός, naked; ὄφις, a sn *Cecilia, &c., &c.*

4. *Labyrinthodonta* (*labyrinth*; ὀδούς, a *extinct.*

Pisces into six orders.

1. Dipnoi (*δι-, double*; *πνοή, breath*): Lepido-ren, &c.
2. Elasmo-branchii (*ἔλασμα, a thin plate*; *βράγ-α, gills*): sharks, &c.
3. Ganoidei (*γάνος, brightness*): lepidosteus, lypterus.
4. Teleostei (*τέλειος, perfect*; *ὀστέον, a bone*): ost living fish.
5. Marsipo-branchii (*μάρσιπος, a pouch*): lamp-ys and hags.
6. Pharyngo-branchii: Amphioxus.

The following table shows the proportion of eight of brain to body, and the relative size of ood cells in Vertebrata.

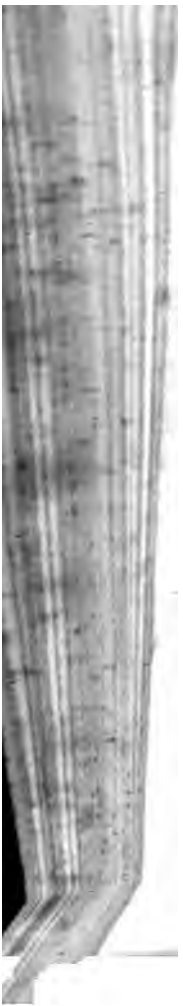
---

roportion of weight of encephalon to weight of body.

Mammalia	1 to 186
Birds	1 to 212
Reptiles	1 to 1321
Fishes	1 to 5568

Size of red blood corpuscles in animals.

Human corpuscles .	$\frac{1}{3300}$ of an inch.
Elephant . . .	$\frac{1}{2700}$ "
Sloth	$\frac{1}{2800}$ "
Ape	$\frac{1}{3400}$ "
Dog	$\frac{1}{3500}$ "
Wolf	$\frac{1}{3600}$ "
Ox	$\frac{1}{4200}$ "
Cat	$\frac{1}{4400}$ "
Horse	$\frac{1}{4600}$ "
Deer	$\frac{1}{5000}$ "
Sheep	$\frac{1}{5300}$ "
Goat	$\frac{1}{6300}$ "
Musk Deer . . .	$\frac{1}{12000}$ "



Birds.

Various species (length) $\frac{1}{1700}$ to $\frac{1}{24}$

Reptiles.

Various species (length) $\frac{1}{1200}$ to $\frac{1}{15}$

Amphibia.

Frog (length)	.	$\frac{1}{1000}$ to $\frac{1}{12}$
Siren (length)	.	. $\frac{1}{42}$
Proteus (length)	.	. $\frac{1}{33}$

Fishes.

Various species (length) $\frac{1}{1150}$ to $\frac{1}{245}$

CHAPTER XIII.

ANSWERS TO EXAMINATION PAPERS.

It is sometimes a matter of difficulty to a student, in answering examination questions, to know how much to say, and in what form it is best to say what he does know upon the subject. In order to give some idea as to the manner in which questions should be answered, I have selected a couple from the University Calendars of 1867 and 1869, and written brief replies to them, as a sort of guide to the student.

1867. '*Describe the principal forms of the respiratory apparatus amongst the Mollusca.*'

Some of the molluscous orders are aquatic in their habits, while others pass a terrestrial existence; the principal modifications of their respiratory organs have reference to this fact.

1st. *The aquatic Mollusca respire by means of branchiæ.* They include the Lamelli-branchiata, Pteropoda, Branchio-gasteropoda, and Cephalopoda.

The respiratory apparatus in the *Lamelli-branchiata* is arranged in the form of four delicate leaves, composed of radiating fibres attached to the body by one extremity, but perfectly free elsewhere; there are two leaves for each lobe of the mantle. The fringes are not only covered with an exquisitely fine network of blood-vessels, but are also richly ciliated, so that the water is continually being changed, and so fresh oxygen constantly brought into contact with the small blood-vessels of the branchiæ.

In the Pteropoda the respiratory organs are situated at the extremity of the wing-like fins or 'feet.'

These wings are very thin, and richly
blood-vessels, whose contents are suffi
fied by direct contact with the oxygen
mixed with the sea water.

The *Branchio-gasteropoda* have their
situated and variously shaped, and, i
with this fact, have been divided into s
such as *Nudi-branchiata*, gasteropods
in whom the branchiæ are freely expo
arborescent fringe from some part of
body; *Infero-branchiata*, gasteropods
branchiæ, resembling two long rows c
placed on the under surface of the body;
branchiata, which order includes all th
of spiral univalve shells, and in whom
are placed internally in the centre of a
to which the water is freely admitted.
as the name implies, arranged like t
comb, and form one, two, or three rov
from the branchial chamber.

The *Cephalopoda* breathe either by
branchial organs. These branchiæ
within the visceral sac, and consist of a
stem, to which are appended a grea
highly vascular laminæ.

2*nd. The Mollusca which respire air*
Pulmo-gasteropoda alone.

The respiratory apparatus of these
Mollusca is arranged as a large, somewh
chamber, to which an opening of consi
situated on the right side of the body
dorsal margin of the shell, conducts t
roof of this respiratory chamber is ver
supplied with blood-vessels, arteries, a
the floor is occupied by a muscular
contracting after the fashion of a

phragm, constantly expels the respired air, which is renewed on the relaxation of the muscle.

1869. '*Describe the process which has been termed the alternation of generations; and give three examples of it.*'

Amongst certain families of invertebrates, duly fertilised ova are produced as the result of sexual intercourse, which ova develop into animals totally unlike their parents, and give birth (non-sexually) to *pseudova*, which in their turn either directly revert to the original type or pass through two, three, or even more generations until their (non-sexual) offspring assumes the likeness of the first parent. This process constitutes what is termed *alternation of generations*, and must be carefully distinguished from *metamorphosis*, in which process the fertilised ova pass through several perfectly distinct types of being before arriving at the mature form, but do not give origin to ova during this process; the original ova themselves completing the cycle of changes.

Metamorphosis is met with amongst insects, and even in one class of vertebrates, viz. the Amphibia. Alternation of generations is confined to the invertebrate kingdom, and chiefly to the lower ranks of this great division; being common amongst the Molluscoida, Cœlenterata, and Protozoa; rarely met with amongst Annulosa; and never amongst the Mollusca. I shall select an example from the three different classes—Cœlenterata, Annuloida, and Annulosa.

1. *Cœlenterata.*—Some Cœlenterata produce fertilised ova, which give origin in their turn to a second generation, without any further sexual intercourse. The form which is evolved from the fertilised ovum is called a *scolex*, which produces secondary forms

by gemmation or fission, called *strobila*. Th
bila, in their turn, produce beings like the
Cœlenterate parent, provided with male and
organs. This last and perfect form is called
glottis.

I will illustrate the alternation of generatic
with amongst this class by an outline of the
duction of a Medusa.

The Medusa produces a vast number of fe
ova, which are very generally ciliated.
ciliated ova swim freely about and increase i
finally, they attach themselves to a fucus or s
and assume a hydra-like form. In this co
they produce an indefinite number of bein
themselves by a process of budding (gemm
these gemmiparously-produced polyps the
velop a number of transverse wrinkles alon
entire body; these wrinkles deepen, and
separate the single animal into a number of t
disc-like bodies, called planulæ. These p
thus set free, rapidly acquire the form and fu
of the perfect acaleph or Medusa from whic
were originally produced.

2. *Annuloida*.—As an example of alterna
generation amongst the Annuloida, I shall sel
transformation of cercariæ into distomata.

The life history of a distoma, or fluke,
follows: The fertilized ova derived from the
distoma grow up into little yellow worms,
two lines in length; these develop (non-se
a numerous progeny of minute animals withi
interior, called *cercariæ*. These cercariæ, es
from the bodies of the worms, or 'nurses' a
are called to distinguish them from true m
move freely about in the water by means of
tail. After a time the animal crawls o

body of a mollusc, and burrowing its way through the integuments of its unwilling entertainer, ensconces itself within the interior of the snail's body (for it is generally a Limnæus that it selects). During this process the tail is lost, and the little entozoon becomes surrounded by a mucous secretion poured out from its own body, which hardening, encloses it in a vitreous-like case. In this condition it remains quiescent for months, but finally bursting its pupa case, makes its way to the liver, where it becomes developed into a veritable distoma.

3. *Annulosa.*—The Daphnia is the only instance afforded by the Crustacea, but there are a few instances amongst the Insecta of the phenomena in question. The female Daphnia, which I will take as an example, presents the remarkable phenomenon of producing true fertilized ova at one season of the year, and unfertilized or *pseudova* at other seasons. These pseudova themselves grow up into little crustaceans, which non-sexually produce other ova, which finally develop into perfect Daphniæ, capable of sexual reproduction.

LONDON: PRINTED BY
SPOTTISWOODE AND CO., NEW-STREET SQUARE
AND PARLIAMENT STREET